MOOLARBEN COAL COMPLEX:
Moolarben Project Stage 2 – Longwalls 101 to 103
Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Extraction Plan
Report produced to:- Support the Extraction Plan for submission to the Department of Planning and Environment (DP&E).

Associated reports:- MSEC353 (Revision E, November 2011) – Moolarben Coal Project Stage 2 – The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Proposed Extraction of Longwalls 1 to 13 in support of a Part 3A Application.

MSEC731 (Revision A, June 2015) – Moolarben Coal Complex – Stage 2 of Moolarben Coal Project – Revised Predictions of Subsidence Impacts resulting from the Proposed UG1 Mine Layout Optimisation Modification.

Background reports available at www.minesubsidence.com:-
- Introduction to Longwall Mining and Subsidence (Revision A)
- General Discussion of Mine Subsidence Ground Movements (Revision A)
- Mine Subsidence Damage to Building Structures (Revision A)
EXECUTIVE SUMMARY

Moolarben Coal Operations Pty Ltd (MCO) operates the Moolarben Coal Complex (MCC), which is located approximately 40 km north east of Mudgee in New South Wales (NSW). MCO has been granted approval to develop Stages 1 and 2 of the Moolarben Coal Project (MCP) under the Environmental Planning and Assessment Act 1979. Approval for Stage 1 of the MCP (05_0117) was granted by the Minister for Planning on 6 September 2007. Approval for Stage 2 of the MCP (08_0135) was granted for the Preferred Project Mine Layout (PrefML) on 30 January 2015.

The MCC includes four approved open cut mines, (known as Open Cut 1 mine (OC1), Open Cut 2 mine (OC2), Open Cut 3 mine (OC3) and Open Cut 4 mine (OC4)), and three approved underground mines, (known as Underground Area 1 (UG1), Underground Area 2 (UG2) and Underground Area 4 (UG4)) and the associated infrastructure.

MCO commenced mining coal from the open cut mine OC1 in May 2010. No secondary extraction has commenced within the three approved underground coal mining operations within the MCC. A Modified Mine Layout for the UG1 Optimisation Modification (Stage 2 Modification 2) was approved in April 2016 (Approved Layout).

MCO is now preparing an Extraction Plan for the extraction of Longwalls 101 to 103 within UG1. During the preparation of the Extraction Plan, MCO introduced a barrier pillar with a total length of 140 m along the alignment of Longwall 102 and reduced the length of Longwalls 101 to 103 by approximately 69 m. The layout of Longwalls 101 to 103 that incorporates these changes is referred to as the Extraction Plan Layout in this report.

MSEC has prepared this subsidence report to support the Longwalls 101-103 Extraction Plan Application. The predictions and impact assessments provided in this report are based on the Extraction Plan Layout.

The locations of the approved MCC open cut mines and underground mines, including UG1, are shown in Drawing No. MSEC867-01, which together with all other drawings, is included in Appendix E.

The introduction of the barrier pillar resulted in a decrease in subsidence predictions above and in the vicinity of the barrier pillar. The reduced longwall lengths resulted in a reduction in the predicted limit of vertical subsidence in these areas and increased the distance between the end of the longwalls and public infrastructure to the north and east of UG1. With the exception of the changes of these, the longwall panel dimensions and layout of Longwalls 101 to 103 do not change for the Extraction Plan Layout. As a result, the overall impact assessments for the natural and built features based on the Extraction Plan Layout are unchanged, or reduce compared to those based on the Approved Layout.

Monitoring and management strategies are being developed for the following built features as part of the Extraction Plan process for Longwalls 101 to 103 based on the Extraction Plan Layout, in consideration of the results of additional assessments and consultation with the infrastructure owners:

- Australian Rail Track Corporation (ARTC) – Sandy Hollow – Gulgong Railway;
- Mid Western Regional Council (MWRC) – local roads (including Ulan-Wollar Road) and associated infrastructure;
- Telstra – telecommunications cables;
- Essential Energy – 66kV powerline and proposed substation; and
- TransGrid – 330 kV electricity transmission line and towers.

Monitoring and management strategies are being developed for the identified natural features as part of the Extraction Plan process for Longwalls 101 to 103 based on the Extraction Plan Layout.

The monitoring and management strategies for built features would aim to achieve the performance measure of safe, serviceable and repairable.
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1.0  INTRODUCTION

1.1. Background

Moolarben Coal Operations Pty Ltd (MCO) operates the Moolarben Coal Complex (MCC), which is located approximately 40 km north east of Mudgee in New South Wales (NSW). MCO has been granted approval to develop Stages 1 and 2 of the Moolarben Coal Project (MCP) under the Environmental Planning and Assessment Act 1979. Approval for Stage 1 of the MCP (05_0117) was granted by the Minister for Planning on 6 September 2007. Approval for Stage 2 of the MCP (08_0135) was granted for the Preferred Project Mine Layout (PrefML) on 30 January 2015.

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MCO is now preparing an Extraction Plan for the extraction of Longwalls 101 to 103 within UG1. During the preparation of the Extraction Plan, MCO introduced a barrier pillar with a total length of 140 m along the alignment of Longwall 102 and reduced the length of Longwalls 101 to 103 by approximately 69 m. The layout of Longwalls 101 to 103 that incorporates these changes is referred to as the Extraction Plan Layout in this report.

The locations of the approved MCC open cut mines and underground mines, including UG1, are shown in Drawing No. MSEC867-01, which together with all other drawings, is included in Appendix E.

Mine Subsidence Engineering Consultants (MSEC) has prepared this subsidence report to support the Extraction Plan for Longwalls 101 to 103. The predictions and impact assessments provided in this report are based on the Extraction Plan Layout, shown in Drawing No. MSEC867-02.

Chapter 2 defines the Study Area and provides a summary of the natural and built features within this area.

Chapter 3 includes overviews of the mine subsidence parameters and the methods that have been used to predict the mine subsidence movements resulting from the extraction of the longwalls.

Chapter 4 provides the maximum predicted subsidence parameters resulting from the extraction of Longwalls 101 to 103 based on the Extraction Plan Layout. Comparisons of these predictions with the maxima based on the Approved Layout are also provided in this chapter.

Chapters 5 to 11 provide the descriptions, predictions and impact assessments for each of the natural and built features within the Study Area based on the Extraction Plan Layout. Comparisons of the predictions for each of these features with those based on the Approved Layout are provided in these chapters. The impact assessments and recommendations have also been provided based on the Extraction Plan Layout.

1.2. Mining Geometry

The layout of Longwalls 101 to 103 is shown in Drawing No. MSEC867-01 in Appendix E. A summary of the longwall dimensions is provided in Table 1.1.

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<th>Overall Void Width Including First Workings (m)</th>
<th>Overall Tailgate Chain Pillar Width (m)</th>
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<td>LW101</td>
<td>2,561</td>
<td>311</td>
<td>-</td>
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<tr>
<td>LW102A</td>
<td>3,292</td>
<td>311</td>
<td>20</td>
</tr>
<tr>
<td>LW102B</td>
<td>1,060</td>
<td>311</td>
<td>20</td>
</tr>
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<td>LW103</td>
<td>4,492</td>
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The sterilised barrier pillar between LW102A and 102B for the Extraction Plan Layout is 140 m in length and Longwalls 101 to 103 have reduced in length by approximately 69 m. With the exception of these changes the longwall geometry for the Extraction Plan Layout is the same as that for the Approved Layout.
1.3. Surface Topography and Seam Information

The UG1 longwalls are surrounded to a large extent by the approved open cut mine areas and the entry to these longwalls will be accessed from the approved OC1 highwalls. The depth of cover to the Ulan Seam above these longwalls varies between a minimum of about 47 m over Longwall 102A, and a maximum of 165 m over Longwall 102B. The seam floor generally dips from the south-west down to the north-east over the entire mining area. It is proposed to mine the DWS and DTP plies of the Ulan Seam.

The surface level contours, DWS seam floor contours, the DTP seam roof contours, DWS plus DTP seam thickness contours and the overburden depth contours to the DTP seam roof are shown in Drawings Nos. MSEC867-03 to MSEC867-07. The depth of cover has also been presented on Drawing No. MSEC867-08 in three zones, of less than 50 m, 50 m to 100 m and greater than 100 m.

The variations in the surface and seam levels across the mining area are illustrated along Cross sections 1, 2 and 3 in Fig. 1.1, Fig. 1.2 and Fig. 1.3, respectively. The locations of these sections are at the prediction lines shown in Drawings Nos. MSEC867-11 to MSEC867-13.
1.4. Geological Details

The surface lithology in the vicinity of the UG1 are shown in Fig. 1.4.

This figure was produced from a geological coalfield map that was downloaded from the Geological Survey of the Department of Primary Industries’ website called Western Coalfield Regional Geology (Northern Part) Geological Sheet 1 1998 -1:100000 Western Coalfield Map.

As can be seen in this figure, the surface lithology of most of the areas over the UG1 is predominantly units from the Narrabeen Group Sandstones and Conglomerates, (Rn), which are coloured in a light blue hatching, as well as areas of Basalt, (Tb). These units overlie areas, which are hatched in a violet colour, that indicates the surface lithology around the longwalls are from the Illawarra Coal Measures (Pi). Other surface lithology units that are shown in this figure, but are not within the Study Area are areas of Quaternary Alluvials (Qa) and Granite (Cg).
A typical stratigraphic section for the Study Area, which was provided by Minerva Geological Services Pty Ltd, is shown in Fig. 1.5. A discussion of the geological units is provided below in Section 1.4.1.

1.4.1. Lithology

The major geological units in the Study Area are, from the youngest to oldest:

- Tertiary aged basalt intrusions and palaeochannel deposits;
- Triassic aged sandstones and conglomerates of the Narrabeen Group;
- Permian aged Illawarra Coal Measures, including the Ulan Seam; and
- Carboniferous aged Ulan Granite.

The tertiary intrusions consist mainly of small plugs and remnant basalt flows of Tertiary age. The approximate surface location of the tertiary basalt within the Study Area, known as basalt caps, are shown on Fig. 1.4. These basalt caps provide soils that are suited to the endangered ecological community the White Box Yellow Box Blakely’s Redgum Woodland and derived Native Grasslands. Approximate locations of these communities are also shown on Drawing No. MSEC867-08.

Tertiary alluvial palaeochannel deposits, with a maximum thickness of 40-50 m, have been identified and described by HydroSimulations (2017) to the north and east of the proposed UG1 longwalls, as shown in Drawing No. MSEC867-07. The infill sediments consist of poorly-sorted semi-consolidated quartzose sands and gravels in a clayey matrix.

The Triassic sandstone, known as Wollar Sandstone, is part of the Narrabeen Group and this sandstone unit is the main outcropping rock formation over the Study Area. Where present, the sandstones are between 14 m and 70 m thick with both massive and strongly cross-bedded units of individual thickness in the range of 1.5 m to 3 m.

![Stratigraphic Column](image)

Permin Illawarra Coal Measures consist of up to six formations that include conglomerate, claystone, mudstone, siltstone, tuff, sandstone and coal with a general northwest strike direction and dip of 1 to 2° to the northeast. A brief description of each formation, provided in Minerva Geological Services, (February 2007), is as follows:

- Farmers Creek Formation: between 6 m to 10 m of siltstone, sandstone, and white cherty claystone;
- State Mine Creek Formation: up to 30 m of interbedded sandstone, siltstone and claystone. The Moolarben Coal Member occurs at the base of the State Mine Creek Formation and is between 2 m and 4 m thick, consisting of tuffaceous mudstone and claystone. The Middle River Coal Member
occurs at the top of the State Mine Creek Formation and is generally less than 2 m thick, consisting of stony coal and claystone;

- Cockabutta Creek Sandstone Member: up to 9 m of predominantly medium to very coarse-grained quartzose sandstone, similar to the Marrangaroo Conglomerate;
- Newnes and Glen Davis Formations: up to 20 m thickness of laminated mudstones, siltstones and fine-grained sandstones;
- Ulan Coal: the major coal development in the licence area. The seam thickness varies from approximately 6 m to 15 m and is divided into 2 units – Upper (comprising, from top down, ULA, UB1, UB2, UC1, UC2) and Lower (comprising from top down, UCL, DTP, DWS, ETP, EBT and ELR). CMK defines the boundary between upper and lower units; and
- Marrangaroo Conglomerate: generally between 2 m and 6 m thick. The conglomerate is quartzose, commonly porous, and has a “gritty” sucrosic texture.

The Carboniferous Ulan Granite forms the basement below the Illawarra Coal Measures. There are four regional structural features, none of which intersect the proposed underground mining areas. The four regional structural features are the Spring Gully Fault Zone, Curra and Greenhill’s Fault, Flat Dip Domain, and Ulan Hinge Line. A detailed description of the surface and subsurface geological features in the lease area is contained in a report by Minerva Geological Services (February 2007).
2.0 IDENTIFICATION OF SURFACE FEATURES

2.1. Definition of the Study Area

The Study Area is defined as the surface area that is likely to be affected by the proposed mining of Longwalls 101 to 103 in the Ulan Seam by MCO. The extent of the Study Area has been calculated by combining the areas bounded by the following limits:

- The 26.5° angle of draw line;
- The predicted vertical limit of subsidence, taken as the 20 mm subsidence contour; and
- Features sensitive to far-field movements.

As the depth of cover above the longwall varies between 47 and 165 m, the 26.5° angle of draw line has been conservatively determined by drawing a line around the outer edge of the longwall voids at a horizontal distance that varies between 24 and 88 m.

The predicted limit of vertical subsidence has been taken as the predicted total 20 mm subsidence contour as determined using the Incremental Profile Method, which is described in Section 3.5. A detailed discussion of the Incremental Profile Method can also be found at http://www.minesubsidence.com in Background Reports in the report titled ‘General Discussion of Mine Subsidence Ground Movements’.

The line defining the Study Area, based on the further extent of the 26.5° angle of draw and the predicted 20 mm subsidence contour line is shown in Drawing No. MSEC867-01. The predicted total 20 mm subsidence contour line resulting from the extraction of Longwalls 101 to 103 was found to be located entirely within the area bounded by the 26.5° angle of draw line.

The Study Area is located wholly within the UG1 Optimisation Modification Study Area which covered mining of Longwalls 101-105 as described in report MSEC731.

There are additional areas that lie outside the Study Area that are expected to experience far-field movements. The surface features which may be sensitive to such movements have been identified in this report and, hence, these features, which are listed below, have been included as part of this study.

- Sandy Hollow – Gulgong Railway Line;
- Electrical Transmission Lines;
- Optical Fibre and Copper Cables;
- Roads;
- Survey Control Marks; and
- Highwalls of the proposed open cut mines and the underground mine entries from these highwalls.

2.2. Natural and Built Features within the Study Area

Many natural and built features within the Study Area can be seen in the 1:25,000 Topographic Map of the area, published by the Central Mapping Authority (CMA), numbered Wollar 88332N. The longwalls have been overlaid on an extract of this CMA map in Fig. 2.1.

There are no private landowners within the Study Area. All land is owned by either MCO, NSW Crown Land or the Mid-Western Regional Council.
Fig. 2.1  Topographic Map Showing Longwalls 101 to 103 and the Study Area
(source: CMA Map No. Wollar 88332N)

A summary of the natural and built features within the Study Area, or relevant to this report with respect to potential far-field movements, is provided in Table 2.1. The locations of these features are shown in Drawings Nos. MSEC867-08 to MSEC867-10, in Appendix E.

The descriptions, predictions and impact assessments for the natural and built features are provided in Chapters 5 through to 11. The section number references are provided in Table 2.1.
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3.0 OVERVIEW OF MINE SUBSIDENCE PARAMETERS AND THE METHOD USED TO PREDICT THE MINE
SUBSIDENCE MOVEMENTS FOR THE LONGWALLS

3.1. Introduction

This chapter provides overviews of mine subsidence parameters and the methods that have been used to predict the mine subsidence movements resulting from the extraction of the longwalls. Further details on longwall mining, the development of subsidence and the methods used to predict mine subsidence movements are provided in the background reports entitled Introduction to Longwall Mining and Subsidence and General Discussion on Mine Subsidence Ground Movements, which can be obtained from www.minesubsidence.com.

3.2. Overview of Conventional Subsidence Parameters

The normal ground movements resulting from the extraction of longwalls are referred to as conventional or systematic subsidence movements. These movements are described by the following parameters:

- **Subsidence** usually refers to vertical displacement of a point, but subsidence of the ground actually includes both vertical and horizontal displacements. These horizontal displacements in some cases, where the subsidence is small beyond the longwall goaf edges, can be greater than the vertical subsidence. Subsidence is usually expressed in units of **millimetres (mm)**.

- **Tilt** is the change in the slope of the ground as a result of differential subsidence, and is calculated as the change in subsidence between two points divided by the distance between those points. Tilt is, therefore, the first derivative of the subsidence profile. Tilt is usually expressed in units of **millimetres per metre (mm/m)**. A tilt of 1 mm/m is equivalent to a change in grade of 0.1 %, or 1 in 1000.

- **Curvature** is the second derivative of subsidence, or the rate of change of tilt, and is calculated as the change in tilt between two adjacent sections of the tilt profile divided by the average length of those sections. Curvature is usually expressed as the inverse of the **Radius of Curvature** with the units of **1/km (km⁻¹)**, but the values of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in **km (km)**.

- **Strain** is the relative differential horizontal movements of the ground. **Normal strain** is calculated as the change in horizontal distance between two points on the ground, divided by the original horizontal distance between them. Strain is typically expressed in units of **millimetres per metre (mm/m)**. **Tensile Strains** occur where the distance between two points increases and **Compressive Strains** occur when the distance between two points decreases. So that ground strains can be compared between different locations, they are typically measured over bay lengths that are equal to the depth of cover between the surface and seam divided by 20.

Whilst mining induced normal strains are measured along monitoring lines, ground shearing can also occur both vertically and horizontally across the directions of monitoring lines. Most of the published mine subsidence literature discusses the differential ground movements that are measured along subsidence monitoring lines, however, differential ground movements can also be measured across monitoring lines using 3D survey monitoring techniques.

- **Horizontal shear deformation** across monitoring lines can be described by various parameters including horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index. It is not possible, however, to determine the horizontal shear strain across a monitoring line using 2D or 3D monitoring techniques.

High deformations along monitoring lines (i.e. normal strains) are generally measured where high deformations have been measured across the monitoring line (i.e. shear deformations). Conversely, high deformations across monitoring lines are also generally measured where high normal strains have been measured along the monitoring line.

The incremental subsidence, tilts, curvatures and strains are the additional parameters which result from the extraction of each longwall. The total subsidence, tilts, curvatures and strains are the accumulative parameters after the completion of each longwall within a series of longwalls. The travelling tilts, curvatures and strains are the transient movements as the longwall extraction face mines directly beneath a given point.

3.3. Far-field Movements

The measured horizontal movements at survey marks which are located beyond the longwall goaf edges and over solid unmined coal areas are often much greater than the observed vertical movements at those marks. These movements are often referred to as far-field movements.
Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain. These movements generally do not result in impacts on natural or built features, except where they are experienced by large structures which are very sensitive to differential horizontal movements.

In some cases, higher levels of far-field horizontal movements have been observed where steep slopes or surface incisions exist nearby, as these features influence both the magnitude and the direction of ground movement patterns. Similarly, increased horizontal movements are often observed around sudden changes in geology or where blocks of coal are left between longwalls or near other previously extracted series of longwalls. In these cases, the levels of observed subsidence can be slightly higher than normally predicted, but these increased movements are generally accompanied by very low levels of tilt and strain.

Far-field horizontal movements and the method used to predict such movements are described in detail in the MSEC731 report.

3.4. Overview of Non-Conventional Subsidence Movements

Conventional subsidence profiles are typically smooth in shape and can be explained by the expected caving mechanisms associated with overlying strata spanning the extracted void. Normal conventional subsidence movements due to longwall extraction are easy to identify where longwalls are regular in shape, the extracted coal seams are relatively uniform in thickness, the geological conditions are consistent and surface topography is relatively flat.

As a general rule, the smoothness of the profile is governed by the depth of cover and lithology of the overburden, particularly the near surface strata layers. Where the depth of cover is greater than say 400 m, the observed subsidence profiles along monitoring survey lines are generally smooth. Where the depth of cover is less than say 100 m, such as the case within the Study Area, the observed subsidence profiles along monitoring lines are generally irregular. Very irregular subsidence movements are observed with much higher tilts and strains at very shallow depths of cover where the collapsed zone above the extracted longwalls extends up to or near to the surface.

Irregular subsidence movements are occasionally observed at the deeper depths of cover along an otherwise smooth subsidence profile. The cause of these irregular subsidence movements can be associated with:

- issues related to the timing and the method of the installation of monitoring lines;
- sudden or abrupt changes in geological conditions;
- steep topography; and
- valley related mechanisms.

Non-conventional movements due to geological conditions and valley related movements are discussed in the following sections.

3.4.1. Non-conventional Subsidence Movements due to Changes in Geological Conditions

It is believed that most non-conventional ground movements are the result of the reaction of near surface strata to increased horizontal compressive stresses due to mining operations. Some of the geological conditions that are believed to influence these irregular subsidence movements are the blocky nature of near surface sedimentary strata layers and the possible presence of unknown faults, dykes or other geological structures, cross bedded strata, thin and brittle near surface strata layers and pre-existing natural joints. The presence of these geological features near the surface can result in a bump in an otherwise smooth subsidence profile and these bumps are usually accompanied by locally increased tilts and strains.

Even though it may be possible to attribute a reason behind most observed non-conventional ground movements, there remain some observed irregular ground movements that still cannot be explained with the available geological information. The term “anomaly” is therefore reserved for those non-conventional ground movement cases that were not expected to occur and cannot be explained by any of the above possible causes.

It is not possible to predict the locations and magnitudes of non-conventional anomalous movements. In some cases, approximate predictions for the non-conventional ground movements can be made where the underlying geological or topographic conditions are known in advance. It is expected that these methods will improve as further knowledge is gained through ongoing research and investigation.

In this report, non-conventional ground movements are being included statistically in the predictions and impact assessments, by basing these on the frequency of past occurrence of both the conventional and non-conventional ground movements and impacts. The analysis of strains provided in Section 4.4 includes those resulting from both conventional and non-conventional anomalous movements. The impact assessments for the natural and built features, which are provided in Chapters 5 through to 11, include
historical impacts resulting from previous longwall mining which have occurred as the result of both conventional and non-conventional subsidence movements.

### 3.4.2. Non-conventional Subsidence Movements due to Steep Topography

Non-conventional movements can also result from increased horizontal movements in the downslope direction where longwalls are extracted beneath steep slopes. In these cases, elevated tensile strains develop near the tops and along the sides of the steep slopes and elevated compressive strains develop near the bases of the steep slopes. The potential impacts resulting from the increased horizontal movements in the downslope direction include the development of tension cracks at the tops and sides of the steep slopes and compression ridges at the bottoms of the steep slopes.

Further discussions on the potential for downslope movements for the steep slopes within the Study Area are provided in Section 5.6.

### 3.4.3. Valley Related Movements

Watercourses may be subjected to valley related movements, which are commonly observed along river and creek alignments in the Southern Coalfield but are less commonly observed in the Western Coalfield, which typically have shallower depths of cover. The reason that valley related movements are less commonly observed in the Western Coalfield could be that the conventional subsidence movements are typically much larger than those observed in the Southern Coalfield, which tend to mask any smaller valley related movements which may occur.

The streams within the UG1 Study Area are less likely to experience noticeable mining induced valley related movements, (i.e. valley closure movements and upsidence in the floors of valleys), because of the relatively shallow depths of cover over these longwalls and the nearby presence of the deep open cut pits that would have reduced the in situ compressive horizontal stresses of the overburden strata between these open cut pits.

### 3.5. The Incremental Profile Method

The predicted conventional subsidence parameters for the longwalls were determined using the Incremental Profile Method, which was developed by MSEC, formally known as Waddington Kay and Associates. The method is an empirical model based on a large database of observed monitoring data from previous mining within the Southern, Newcastle, Hunter and Western Coalfields of New South Wales and from mining in the Bowen Basin in Queensland.

The database consists of detailed subsidence monitoring data from many mines and collieries in NSW including: Angus Place, Appin, Baal Bone, Bellambi, Beltana, Blakefield South, Bulli, Carborough Downs, Chain Valley, Clarence, Coalcliff, Cook, Cooranbong, Cordeaux, Corrimal, Cumnock, Dartbrook, Delta, Dendrobium, Eastern Main, Ellalong, Fernbrook, Glennies Creek, Grassstree, Gretley, Invincible, John Darling, Kemira, Kestrel, Lambton, Liddell, Mandalong, Metropolitan, Mt. Kembla, Moranbah, Munmorah, Nardell, Newpac, Newstan, Newvale, Newvale 2, South Bulga, South Bulli, Springvale, Stockton Borehole, Teralba, Tahmoor, Tower, Wambo, Wallarah, Western Main, Ulan, United, West Cliff, West Wallsend, and Wyee.

The database consists of the observed incremental subsidence profiles, which are the additional subsidence profiles resulting from the extraction of each longwall within a series of longwalls. It can be seen from the normalised incremental subsidence profiles within the database, that the observed shapes and magnitudes are reasonably consistent where the mining geometry and local geology are similar.

Subsidence predictions made using the Incremental Profile Method use the database of observed incremental subsidence profiles, the longwall geometries, local surface and seam information and geology. The method has a tendency to over-predict the conventional subsidence parameters (i.e. is slightly conservative) where the mining geometry and geology are within the range of the empirical database. The predictions can be further tailored to local conditions where observed monitoring data is available close to the mining area.

Further details on the Incremental Profile Method can be obtained from [www.minesubsidence.com](http://www.minesubsidence.com).

The Incremental Profile Method model developed for the UG1 Optimisation Modification has been used and updated for subsidence predictions for this study. It is noted that, as per the UG1 Optimisation Modification, maximum subsidence of 65% as a proportion of the extracted seam has been conservatively predicted.
3.6. Calibration and Testing of the Incremental Profile Method

The standard Incremental Profile Method was calibrated using nearby monitoring sites that have similar geology. The calibration and testing of the Incremental Profile Method is outlined in detail in the MSEC731 report.
4.0 MAXIMUM PREDICTED SUBSIDENCE PARAMETERS FOR LONGWALLS 101 to 103

4.1. Introduction

The following sections provide the maximum predicted conventional subsidence parameters resulting from the extraction of Longwalls 101 to 103. The predicted subsidence parameters and the impact assessments for the natural and built features are provided in Chapters 5 to 11.

It should be noted that the predicted conventional subsidence parameters were obtained using the Incremental Profile Method, which was calibrated to local conditions based on the available monitoring data from nearby collieries.

The maximum predicted subsidence parameters and the predicted subsidence contours provided in this report describe and show the conventional movements and do not include the valley related upsidence and closure movements, nor the effects of faults and other geological structures. Such effects have been addressed separately in the impact assessments for each feature provided in Chapters 5 to 11.

4.2. Maximum Predicted Conventional Subsidence, Tilt and Curvature

The maximum predicted conventional subsidence parameters resulting from the extraction of Longwalls 101 to 103 were determined using the calibrated Incremental Profile Method. The predicted subsidence contours are irregular due to the shallow depths of cover. The maximum predicted tilts and curvatures are very localised and therefore do not necessarily represent the overall (i.e. macro) ground movements. The magnitudes of the localised tilts greater than 100 mm/m and the localised curvatures greater than 3.0 km⁻¹ become less meaningful and, therefore, the specific values have not been presented. Revised standards for reporting adopted by MSEC may result in slight differences in reported values compared with previous reports.

A summary of the maximum predicted values of incremental conventional subsidence, tilt and curvature, due to the extraction of each of the longwalls based on the Extraction Plan Layout, is provided in Table 4.1.

<table>
<thead>
<tr>
<th>Longwall</th>
<th>Maximum Predicted Incremental Conventional Subsidence (mm)</th>
<th>Maximum Predicted Incremental Conventional Tilt (mm/m)</th>
<th>Maximum Predicted Incremental Conventional Hogging Curvature (km⁻¹)</th>
<th>Maximum Predicted Incremental Conventional Sagging Curvature (km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Due to LW101</td>
<td>2250</td>
<td>65</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>Due to LW102A</td>
<td>2200</td>
<td>&gt; 100</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>Due to LW102B</td>
<td>2150</td>
<td>45</td>
<td>1.6</td>
<td>1.4</td>
</tr>
<tr>
<td>Due to LW103</td>
<td>2250</td>
<td>70</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
</tbody>
</table>

The predicted total conventional subsidence contours, resulting from the extraction of Longwalls 101 to 103 are shown in Drawings Nos. MSEC867-11 to MSEC867-13. A summary of the maximum predicted values of total conventional subsidence, tilt and curvature, after the extraction of each of the longwalls based on the Extraction Plan Layout, is provided in Table 4.2. The predicted tilts provided in this table are the maxima after the completion of each of the longwalls. The predicted curvatures are the maxima at any time during or after the extraction of each of the longwalls.

<table>
<thead>
<tr>
<th>Longwalls</th>
<th>Maximum Predicted Total Conventional Subsidence (mm)</th>
<th>Maximum Predicted Total Conventional Tilt (mm/m)</th>
<th>Maximum Predicted Total Conventional Hogging Curvature (km⁻¹)</th>
<th>Maximum Predicted Total Conventional Sagging Curvature (km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>After LW101</td>
<td>2250</td>
<td>65</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>After LW102A</td>
<td>2400</td>
<td>&gt; 100</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>After LW102B</td>
<td>2400</td>
<td>&gt; 100</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>After LW103</td>
<td>2400</td>
<td>&gt; 100</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
</tbody>
</table>
The maximum predicted total conventional tilt is greater than 100 mm/m (i.e. > 10 %), which represents a change in grade greater than 1 in 10. The maximum predicted total conventional curvatures are greater than 3 km⁻¹ hogging and sagging, which represent minimum radii of curvature of less than 0.33 km.

The predicted conventional subsidence parameters vary across the Study Area as the result of, amongst other factors, variations in the depths of cover, and extraction heights. To illustrate this variation, the predicted profiles of conventional subsidence, tilt and curvature have been determined along Prediction Line 1, 2 and 3, the locations of which are shown in Drawings Nos. MSEC867-11 to MSEC867-13.

The predicted profiles of vertical subsidence, tilt and curvature along Prediction Lines 1, 2 and 3, resulting from the extraction of Longwalls 101 to 103, are shown in Figs. C.01 to C.03, in Appendix C. The predicted incremental profiles along the prediction lines, after the extraction of each of the longwalls based on the Extraction Plan Layout, are shown as solid blue lines. The predicted total profiles based on the Approved Layout are shown as the red lines for comparison.

### 4.3. Comparison of Maximum Predicted Conventional Subsidence, Tilt and Curvature

The comparison of the maximum predicted subsidence parameters resulting from the extraction of Longwalls 101 to 103, based on the Extraction Plan Layout, with those based on the Approved Layout is provided in Table 4.3. The values are the maxima anywhere above the longwall layouts.

<table>
<thead>
<tr>
<th>Layout</th>
<th>Maximum Predicted Total Conventional Subsidence (mm)</th>
<th>Maximum Predicted Total Conventional Tilt (mm/m)</th>
<th>Maximum Predicted Total Conventional Hogging Curvature (km⁻¹)</th>
<th>Maximum Predicted Total Conventional Sagging Curvature (km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approved Layout (LW101-103) (Report No. MSEC731)</td>
<td>2400</td>
<td>&gt; 100</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>Extraction Plan Layout (Report No. MSEC867)</td>
<td>2400</td>
<td>&gt; 100</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
</tbody>
</table>

It can be seen from the above table, that the maximum predicted total subsidence parameters based on the Approved Layout are the same as those for the Extraction Plan Layout for Longwalls 101 to 103. Whilst the specific values of the maximum tilt and curvatures are not shown, due to these representing the localised irregular movements rather than the macro (i.e. overall) movements, these parameters do not change.

### 4.4. Predicted Strains

The prediction of strain is more difficult than the predictions of subsidence, tilt and curvature. The reason for this is that strain is affected by many factors, including ground curvature and horizontal movement, as well as local variations in the near surface geology, the locations of pre-existing natural joints at bedrock, and the depth of bedrock. Survey tolerance can also represent a substantial portion of the measured strain, in cases where the strains are of a low order of magnitude. The profiles of observed strain, therefore, can be irregular even when the profiles of observed subsidence, tilt and curvature are relatively smooth.

For this reason, the predicted strains provided in this report have been based on statistical analyses of strains measured in the NSW Coalfields to account for this variability.

It has been found, for single-seam mining conditions, that applying a constant factor to the predicted maximum curvatures provides a reasonable prediction for the maximum normal or conventional strains. The locations that are predicted to experience hogging or convex curvature are expected to be net tensile strain zones and locations that are predicted to experience sagging or concave curvature are expected to be net compressive strain zones. In the Newcastle, Hunter and Western Coalfields, it has been found that a factor of 10 provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains, for single-seam mining conditions.

The maximum predicted conventional curvatures resulting from the extraction of the longwalls are greater than 3 km⁻¹ hogging and sagging. Adopting a factor of 10, the maximum predicted conventional strains, due to the proposed mining are greater than 30 mm/m tensile and compressive. Localised and elevated strains greater than the predicted conventional strains can also occur, as the result of non-conventional movements, which was discussed in Section 3.4.

At a point, however, there can be considerable variation from the linear relationship, resulting from non-conventional movements or from the normal scatters which are observed in strain profiles. When
expressed as a percentage, observed strains can be many times greater than the predicted conventional strain for low magnitudes of curvature.

The range of potential strains above the longwalls has been assessed using monitoring data from previously extracted panels in the Hunter, Newcastle and Western Coalfields, for single-seam conditions, where the longwall width-to-depth ratios and extraction heights were similar to those of the longwalls. Comparisons of the void widths, depths of cover, width-to-depth ratios and extraction heights for the longwalls with those for the historical cases are provided in Table 4.4.

Table 4.4  Comparison of the Mine Geometry for the Longwalls 101 to 103 with Longwalls in the Hunter, Newcastle and Western Coalfields used in the Strain Analysis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Longwalls 101 to 103</th>
<th>Longwalls Used in Strain Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range</td>
<td>Average</td>
</tr>
<tr>
<td>Width</td>
<td>311</td>
<td>311</td>
</tr>
<tr>
<td>Depth of Cover</td>
<td>47 – 165</td>
<td>120</td>
</tr>
<tr>
<td>W/H Ratio</td>
<td>1.9 – 6.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Extraction Height</td>
<td>3.2 – 3.5</td>
<td>3.4</td>
</tr>
</tbody>
</table>

It can be seen from the above table that the range of the panel width-to-depth ratios used in the strain analysis are between 1.7 and 6.4, with an average ratio of 2.5, which is similar to the range for Longwalls 101 to 103. The range of extraction heights for the longwalls used in the strain analysis are between 2.2 m and 4.2 m, with an average of 3.0 m, which is slightly less than the average extraction height for Longwalls 101 to 103. The strain analysis, therefore, should provide a reasonable indication of the range of potential strains for the longwalls.

The data used in the analysis of observed strains included those resulting from both conventional and non-conventional anomalous movements, but did not include those resulting from valley related movements. The strains resulting from damaged or disturbed survey marks have also been excluded.

A number of probability distribution functions were fitted to the empirical monitored strain data. It was found that a Generalised Pareto Distribution (GPD) provided a good fit to the raw strain data. Confidence levels have been determined from the empirical strain data using the fitted GPDs. In the cases where survey bays were measured multiple times during a longwall extraction, the maximum tensile strain and the maximum compressive strain were used in the analysis (i.e. single tensile strain and single compressive strain measurement per survey bay).

4.4.1. Analysis of Strains Measured in Survey Bays

For features that are in discrete locations, such as building structures, farm dams and archaeological sites, it is appropriate to assess the frequency of the observed maximum strains for individual survey bays.

Predictions of Strain Above Goaf

The survey database has been analysed to extract the maximum tensile and compressive strains that have been measured at any time during mining, for survey bays that were located directly above goaf or the chain pillars that are located between the extracted longwalls. The frequency distribution of the maximum observed tensile and compressive strains measured in survey bays above goaf is provided in Fig. 4.1. The probability distribution functions, based on the fitted GPDs, are also shown in this figure.
Confidence levels have been determined from the empirical strain data using the fitted GPDs. In the cases where survey bays were measured multiple times during a longwall extraction, the maximum tensile strain and the maximum compressive strain were used in the analysis (i.e. single tensile strain and single compressive strain measurement per survey bay).

The 95 % confidence levels for the maximum total strains that the individual survey bays experienced at any time during mining are 10 mm/m tensile and 13 mm/m compressive. The 99 % confidence levels for the maximum total strains that the individual survey bays experienced at any time during mining were 22 mm/m tensile and 31 mm/m compressive. The maximum strains measured along the monitoring lines were greater than 50 mm/m tensile and 100 mm/m compressive. These maximum strains represent very localised movements in the locations of large surface deformations.

The predicted conventional strains are greater than the predicted 95 and 99 % confidence levels for the strains that include non-conventional movements, as the irregular strains are isolated and extreme events. This is demonstrated by the maximum observed strains that are considerably greater than the predicted confidence levels and the conventional strains.

It is noted, that these strains are based on monitoring data having an average width-to-depth ratio of 2.5 and, therefore, the strains above the longwalls are expected to be greater, on average, where the width-to-depth ratios are greater than 2.5 (i.e. depths of cover less than 125 m) and are expected to be less, on average, where the width-to-depth ratios are less than 2.5 (i.e. depths of cover greater than 125 m).

**Predictions of Strain Above Solid Coal**

The survey database has also been analysed to extract the maximum tensile and compressive strains that have been measured at any time during mining for survey bays that were located beyond the goaf edges of the mined panels and positioned on unmined areas of coal, i.e. outside the longwall panels, but within 200 m of the nearest longwall goaf edge.

The histogram of the maximum observed tensile and compressive strains measured in survey bays above solid coal is provided in Fig. 4.2. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

The 95 % confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining are 3.3 mm/m tensile and 3.0 mm/m compressive. The 99 % confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining are 9.2 mm/m tensile and 14.4 mm/m compressive.

![](image)
Fig. 4.2 Distributions of the Measured Maximum Tensile and Compressive Strains in the Hunter, Newcastle and Western Coalfields for Survey Bays located above Solid Coal within 200 m of the nearest longwall

Some surface features discussed in this report are located greater than 200 m from the Longwalls 101 to 103, including the railway line, transmission line and fibre optic cable. The survey database has been analysed to extract the maximum tensile and compressive strains that have been measured at any time during mining for survey bays that were located beyond the goaf edges of the mined panels and positioned on unmined areas of coal between 200 m and 600 m of the nearest longwall goaf edge.

The histogram of the maximum observed tensile and compressive strains measured in survey bays above solid coal is provided in Fig. 4.3. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

The 95 % confidence levels for the maximum total strains that the individual survey bays above solid coal (beyond 200 m) experienced at any time during mining are 1.6 mm/m tensile and 1.5 mm/m compressive. The 99 % confidence levels for the maximum total strains that the individual survey bays above solid coal (beyond 200 m) experienced at any time during mining are 2.9 mm/m tensile and 3.0 mm/m compressive. It is noted that these measured strains also include components of survey tolerance.
4.4.2. Analysis of Strains Measured Along Whole Monitoring Lines

For linear features such as roads, cables and pipelines, it is more appropriate to assess the frequency of the maximum observed strains along whole monitoring lines, rather than for individual survey bays. That is, an analysis of the maximum strains measured anywhere along the monitoring lines, regardless of where the strain actually occurs.

The histogram of maximum observed total tensile and compressive strains measured anywhere along the monitoring lines, at any time during or after mining, is provided in Fig. 4.4.
**Fig. 4.4** Distributions of Measured Maximum Tensile and Compressive Strains Anywhere along the Monitoring Lines in the Hunter, Newcastle and Western Coalfields

It can be seen from the above figure, that 24 of the 48 monitoring lines (i.e. 50%) have recorded maximum total tensile strains of 10 mm/m, or less, and that 36 monitoring lines (i.e. 75%) have recorded maximum compressive strains of 10 mm/m, or less. Also, 20 of the 46 monitoring lines (i.e. 43%) have recorded maximum compressive strains of 10 mm/m, or less, and that 28 of the monitoring lines (i.e. 60%) have recorded maximum compressive strains of 20 mm/m, or less.

### 4.5. Horizontal Movements

The predicted conventional horizontal movements over the longwalls are calculated by applying a factor to the predicted conventional tilt values. A factor of 10 is generally adopted for the Western Coalfield, being the same factor as that used to determine conventional strains from curvatures, and this has been found to give a reasonable correlation with measured data. This factor will in fact vary and will be higher at low tilt values and lower at high tilt values. The application of this factor will therefore lead to over-prediction of horizontal movements where the tilts are high and under-prediction of the movements where the tilts are low.

The maximum predicted total conventional tilt within the Study Area, at any time during or after the extraction of the longwalls, is greater than 100 mm/m. The application of the factor of 10 is likely to be conservative at this high magnitude of predicted tilt. The maximum predicted conventional horizontal movement is, therefore, greater than 1000 mm, i.e. 100 mm/m multiplied by a factor of 10. This prediction is considered to be conservative, with the actual horizontal movements expected to be generally less than 500 mm.

Conventional horizontal movements do not directly impact on natural or built features, rather impacts occur as a result of differential horizontal movements. Strain is the rate of change of horizontal movement. The impacts of strain on the natural and built features are addressed in the impact assessments for each feature, which have been provided in Chapters 5 to 11.

### 4.6. Predicted Far-field Horizontal Movements

In addition to the conventional subsidence movements that have been predicted above and adjacent to Longwalls 101 to 103, it is also likely that far-field horizontal movements will be experienced during the extraction of the longwalls. A detailed discussion of far-field horizontal movements and the method used to predict such movements is provided in the MSEC731 report.
An empirical database of observed incremental far-field horizontal movements has been compiled using available monitoring data from the NSW Coalfields, but this database predominately includes measurements from the Southern Coalfield. The far-field horizontal movements are generally observed to be orientated towards the extracted longwall. At very low levels of far-field horizontal movements, however, there is a higher scatter in the orientation of the observed movements.

The observed incremental far-field horizontal movements, resulting from the extraction of single longwalls, are shown in Fig. 4.5. The observed directions of these far-field horizontal movements were generally observed to be orientated towards the extracted longwall.

This plot of far-field horizontal movements includes various multi-seam mining cases and some sites with components from valley closure effects. The confidence levels, based on fitted GPDs, have also been shown in this figure to illustrate the spread of the data. The magnitude of these movements decrease with distance from the mined edges however, there have been cases where the observed far-field horizontal movements beyond the edges of the mined panels have approached 400 mm. The highest observed far-field horizontal movements are multi seam cases that are located close to large valleys.

This data includes some of the available observed far-field horizontal movements that have been measured at Ulan Coal Mine and other observed data from other regions where the depths of cover are also relatively shallow. There is extensive far-field monitoring data from the Southern Coalfield, which has also been included in this figure, where the depths of cover are greater than that at the mine. The available far-field incremental horizontal movement data has therefore been replotted, as shown in Fig. 4.6, against the distances from the nearest edge of the incremental panel divided by the depth of cover.

![Observed Incremental Horizontal Movement versus Distance to Active Longwall](image)

Fig. 4.5 Observed Incremental Far-Field Horizontal Movements (mm) from many regions in NSW plotted against the distance to the nearest edge of the mined panel (m)
Fig. 4.6 Observed Incremental Far-Field Horizontal Movements (mm) from many regions in NSW versus the distance to the nearest edge of the mined panel divided by the depth of cover (m/m)

Fig. 4.6 replots the available far-field horizontal movement data that is shown in Fig. 4.5 allowing for the influence of changing depths of cover and this plot is for appropriate for use at MCC. This plot still includes those cases where higher movements occurred because of multi-seam mining and valley closure effects.

As successive longwalls within a series of longwall panels are mined, the magnitudes of the incremental far-field horizontal movements decrease. This is possibly due to the fact that once the in situ stresses in the strata within the collapsed zones above the first few extracted longwalls has been redistributed, the potential for further movement is reduced. The total far-field horizontal movement is not, therefore, the sum of the incremental far-field horizontal movements for the individual longwalls.

The impacts of far-field horizontal movements on the natural features and items of surface infrastructure within the vicinity of the Extraction Plan Layout is expected to be insignificant, except where they occur at large structures, such as railway lines and roads, which may be sensitive to small differential movements and may require monitoring and maintenance to remain in a safe and serviceable condition.

4.6.1. Influence of Palaeochannel near UG1 on Horizontal Far-field Movements

As detailed in Section 1.4.1 there are palaeochannel deposits, with a maximum thickness of 40-50 m, located to the north and east of the proposed UG1 longwalls, where the depths of cover range from 90 to 130 m, as is shown in Drawing No. MSEC687-07 and as is described by HydroSimulations (2017).

These palaeochannels are remnants of inactive river or stream channels that have been later filled in or buried by younger sediment that can be stronger or weaker than the original strata. Palaeochannels have caused significant differences between the predicted and the observed levels of subsidence at other collieries. Where the original strata were eroded away to form a river channel and then the channel was filled in with stronger materials that formed massive conglomerate channels, then, the observed subsidence near these channels was found to be less than was expected because these channels were capable of spanning over voids.

However, where the original strata were filled in with weaker material, such as unconsolidated sediments, then, the observed subsidence under these channels can be greater than was expected because these weaker materials failed and subsided more readily than the original strata. But, where the original strata were filled in with weak unconsolidated sediments and mining occur besides, but not under these palaeochannels, then, the observed far-field horizontal movements and vertical subsidence beyond these channels can be less than was expected beyond the palaeochannels.
At MCC the palaeochannels to the north and east of the proposed UG1 longwalls were formed when Permian strata layers were replaced with infill sediments consisting of poorly-sorted semi-consolidated quartzose sands and gravels in a clayey matrix, i.e. unconsolidated sediments, unsaturated alluvium and low permeability clays. The presence of these palaeochannel materials can modify the subsidence ground movements beyond the end of the longwalls, (depending on the depth of the channels, and its location with respect to the panel edges). Groundwater associated with the palaeochannel is discussed in a report by HydroSimulations (2017).

Since these palaeochannel sediments are located away from the edges of the longwalls, then, their presence should not significantly affect the subsidence directly over the longwalls. However, the presence of this palaeochannel should result in less subsidence within these alluvial and unconsolidated sediment areas and reduced far-field movements within and beyond these channels.

4.6.2. Influence of the Open Cut on Horizontal Far-field Movements

An open cut mining area (OC1) which recently ceased operation is located to the north west of the longwalls as shown in Drawing No. MSEC877-02. Access to the UG1 longwalls will be via the OC1 pit. Open cut mining areas are also located to the south west (OC2) and south east (OC4). Extraction within OC2 and OC4 has commenced.

The open cut pits extract the overburden material and the target coal seam. i.e. down to the seam floor level of the longwalls. The effect of the removal of this material is to relieve or redistribute much of the in situ stress in the overburden strata adjacent to the pit. With the removal of the overburden material, the potential for far-field effects to develop in the vicinity of the pit are significantly reduced.

With rehabilitated open cut mine areas, the overburden material has been replaced, typically with other stripped material which is compacted by vehicle tracking during the emplacement process. Potential for far-field movements where the open cut pit has been fully rehabilitated between the longwalls and the outer natural overburden is expected to be significantly reduced, similar to the open cut pit, as the emplaced material is unlikely to support any significant stress redistribution.

4.7. Potential for increased subsidence between Longwall 102A and 102B

The unmined coal barrier between Longwalls 102A and 102B will have solid coal dimensions of 140 m by 310 m.

It is possible that increased vertical subsidence will be observed above the barrier pillar. There have been a number of examples in NSW where subsidence monitoring has shown increased vertical subsidence of the surface in areas that are located directly above an isolated coal barrier. Magnitudes of settlement have been observed between 50 and 150 mm above an isolated coal barrier which is greater than predicted using the Standard Incremental Profile Method. The cause of the additional subsidence has not been proven, but it is thought that it is a result of factors including a general relaxation of in-situ stress in the strata within the coal barrier and additional vertical load on the coal barrier.

Whilst additional subsidence has not always been observed in these situations, they have occurred in a sufficient number of cases to acknowledge that a similar occurrence may be observed between Longwalls 102A and 102B.

While observed subsidence may exceed predictions for the coal barrier, subsidence monitoring has shown that it is usually accompanied by relatively low conventional tilts, curvature and strains. The potential for impacts above the coal pillar, therefore, do not significantly change.

It is recommended that allowance be made for additional vertical movements up to approximately 50 mm to 150 mm for the coal barrier pillar between Longwalls 102A and 102B.

4.8. Non-Conventional Ground Movements

It is likely non-conventional ground movements will occur within the Study Area, due to near surface geological conditions and steep topography, which were discussed in Section 3.4. These non-conventional movements are often accompanied by elevated tilts and curvatures which are likely to exceed the conventional predictions.

The potential for non-conventional movements associated with steep topography is discussed in the impact assessments for the steep slopes provided in Section 5.6.

In most cases, it is not possible to predict the exact locations or magnitudes of the non-conventional anomalous movements due to near surface geological conditions. For this reason, the strain predictions provided in this report are based on a statistical analysis of measured strains, including both conventional and non-conventional anomalous strains, which is discussed in Section 4.4. In addition to this, the impact assessments for the natural and built features, which are provided in Chapters 5 to 11, include historical
impacts resulting from previous longwall mining which have occurred as a result of both conventional and non-conventional subsidence movements.

4.9. General Discussion on Mining Induced Ground Deformations

Longwall mining can result in surface cracking, heaving, buckling, humping and stepping at the surface. The extent and severity of these mining induced ground deformations are dependent on a number of factors, including the mine geometry, depth of cover, overburden geology, locations of natural joints in the bedrock, the presence of near surface geological structures and mining conditions.

Fractures and joints in bedrock occur naturally during the formation of the strata and from subsequent erosion and weathering processes. Longwall mining can result in additional fracturing in the bedrock, which tends to occur in the tensile zones, but fractures can also occur due to buckling of the surface beds in the compressive zones. The incidence of visible cracking at the surface is dependent on the pre-existing jointing patterns in the bedrock as well as the thickness and inherent plasticity of the soils that overlie the bedrock.

As subsidence occurs, surface cracks will generally appear in the tensile zone, i.e. within 0.1 to 0.4 times the depth of cover from the longwall perimeters. Most of the cracks will occur within a radius of approximately 0.1 times the depth of cover from the longwall perimeters. The cracks will generally be parallel to the longitudinal edges or the ends of the longwalls. Surface cracking normally develops behind the extraction face up to a horizontal distance equal to around half the depth of cover and, hence, the cracking in any location normally develops over a period of around two to four weeks.

At shallow depths of cover, it is also likely that transient surface cracks will occur above and parallel to the moving extraction face, i.e. at right angles to the longitudinal edges of the longwall, as the subsidence trough develops. The larger and more permanent cracks, however, are usually located in the final tensile zones around the perimeters of the longwalls. Open fractures and heaving, however, can also occur due to the buckling of surface beds that are subject to compressive strains. An example of crack patterns that develop in shallow depths of cover is shown in Fig. 4.7 below.

Fig. 4.7 Survey of Major Fracture Pattern at Approx. 110m Cover
(Source: Klenowski, ACARP C5016, 2000)

Over previously mined longwalls, typical surface crack widths in the order of 100 mm and step heights in the order of 100 mm have been commonly observed at shallow depths of cover, say less than 200 m. Larger crack widths have been observed with shallow depths of cover where thicker seams are extracted, where mining occurs near or beneath steep terrain, where thick massive strata beams are present, or where multiple cracks joint to form a broader surface deformation.

Localised cracking and stepping greater than 500 mm have been observed at other collieries with similar depths of cover in the NSW Coalfields. These larger tensile cracks tend to be isolated and located above and around the perimeters of the longwalls and along the tops of steep slopes, due to down slope movements resulting from the extraction of the longwalls. The typical surface cracks and these larger isolated cracks can normally be easily identified and remediated to prevent loss of surface water – Klenowski (ACARP C5016, 2000).
Experience in NSW has found that the severity and frequency of surface cracking reduces as the depth of cover to the extraction increases. The following photographic records provide examples of surface cracking resulting from NSW longwall mining operations.

Fig. 4.8 Photographs of Isolated Surface Cracking above multi-seam longwall extraction above Blakefield South Mine in the Hunter Coalfield around 200m cover

Fig. 4.9 Surface Step 0.5m high, above Longwall C at Ulan Coal Mine. 260m void width, 1.27m maximum observed subsidence, approximately 180m cover. (Ulan Longwall C End of Panel Subsidence Report)
Fig. 4.10  Isolated Surface Step 0.8m high, above Longwall E at Ulan Coal Mine. 260m void width, 1.31m maximum observed subsidence, 130 to 145m cover.  
(Ulan Longwall E End of Panel Subsidence Report)

Fig. 4.11  Photographs of Isolated Surface Cracking parallel to longwall tailgate above Longwall 26 at Ulan Coal Mine. 410m void width, 1.38m maximum observed subsidence, 240m cover.  
(Ulan Longwall 26 End of Panel Subsidence Report)
The depths of cover over the underground mining areas vary from 47 m to 165 m. Where the depths of cover above Longwalls 101 to 103 are less than 100 m, surface cracking is expected to be typically in the order of 150 to 200 mm wide, but could be as large as 500 mm wide where the depths of cover are the shallowest. The surface crack widths are likely to be smaller where the depths of cover are greater, or where the surface cracks result from the travelling wave. Where the depths of cover above Longwalls 101 to 103 are 100 to 150 m, the surface crack widths are expected to be typically in the order of 100 to 150 mm wide.

The surface cracking and deformation could result in safety issues (i.e. trip hazards), affect vehicle access (i.e. large deformations in access tracks), or result in increased erosion (especially along the drainage lines and the steeper slopes).

Management strategies and remediation measures should be developed for the surface cracking and deformations, which could include the following:

- Visual monitoring of the surface in the active subsidence zone, to identify the larger surface cracking and deformations which could affect safety, access, or increase erosion; and
- Establish methods for surface remediation, which could include infilling of surface cracks with soil or other suitable materials, or by locally regrading and compacting the surface. In some cases, erosion protection measures may be needed, such as the planting of vegetation in order to stabilise the steeper slopes in the longer term.
5.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE NATURAL FEATURES WITHIN THE STUDY AREA

The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the natural features located within the Study Area for Longwalls 101 to 103. The predicted parameters for each of the natural features have been compared to the predicted parameters based on the Approved Layout. Supporting impact assessments for the natural features have also been undertaken by other specialist consultants for the Extraction Plan Layout.

5.1. Natural Features

As listed in Table 2.1, the following natural features were not identified within the Study Area nor in the immediate surrounds:

- catchment areas or declared special areas;
- rivers or creeks;
- springs;
- seas or lakes;
- shorelines;
- natural dams;
- escarpments;
- land prone to flooding or inundation;
- swamps, wetlands or water related ecosystems;
- national parks;
- state forests;
- state conservation areas; and
- other significant natural features.

The following sections provide the descriptions, predictions and impact assessments for the natural features which have been identified within or in the vicinity of the Study Area.

5.2. Aquifers and Known Ground Water Resources

The aquifers and groundwater resources within the vicinity of the UG1 have been investigated and are described in the report by HydroSimulations (2017). The Extraction Plan Layout does not pass beneath water bearing palaeochannel sediments (HydroSimulations, 2017).

5.3. Drainage Lines

5.3.1. Description of the Drainage Lines

A number of small drainage lines have been identified above the longwalls and within the UG1 Study Area, as shown in Drawing No. MSEC867-08. The larger drainage lines have been numbered as Drainage Lines 4, 5, 6 and 7 as shown in Drawing No. MSEC867-08.

Some of these drainage lines flow to the north and west off the UG1 area towards the OC1 Pit. Other drainage lines currently flow off the UG1 area to the north and east towards the Murragamba Creek or Wilpinjong Creek. However, after the OC4 Pit is formed most of these drainage lines will either be diverted or flow into this Pit.

Drainage Lines 4 and 5 are located within the footprint of the approved out-of-pit emplacement and are in the process of being covered. Drainage Line 6 is located within the Study Area, however is located outside the predicted 20 mm subsidence contour and will experience negligible subsidence movements from the extraction of Longwalls 101 to 103. Hence subsidence predictions are not provided for these three drainage lines.

The only numbered drainage line predicted to experience greater than negligible subsidence from Longwalls 101 to 103 is called Drainage Line 7.

5.3.2. Predictions for the Drainage Lines

The unnumbered drainage lines are located across the Study Area and are likely, therefore, to be subjected to the full range of predicted conventional subsidence movements which are provided in Section 4.0.
The predicted profiles of vertical subsidence, tilt and curvature along the alignment of Drainage Line 7, based on the Extraction Plan Layout, are shown in Fig. C.04 in Appendix C. The predicted incremental profiles along the drainage line, due to the extraction of each of the longwalls, are shown as dashed black lines. The predicted total profiles along the drainage line, after the extraction of each of the longwalls, are shown as solid blue lines. The predicted total profiles based on the Approved Layout are shown as the dashed red and the solid red lines for comparison.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the drainage line, resulting from the extraction of Longwalls 101 to 103, is provided in Table 5.1. The values are the predicted maxima within the Study Area.

### Table 5.1 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for Drainage Line 7 Resulting from the Extraction of Longwalls 101 to 103

<table>
<thead>
<tr>
<th>Longwall</th>
<th>Maximum Predicted Total Conventional Subsidence (mm)</th>
<th>Maximum Predicted Total Conventional Tilt (mm/m)</th>
<th>Maximum Predicted Total Hogging Curvature (km⁻¹)</th>
<th>Maximum Predicted Total Sagging Curvature (km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longwall 101</td>
<td>&lt; 20</td>
<td>&lt; 0.5</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Longwall 102</td>
<td>45</td>
<td>2.5</td>
<td>0.1</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Longwall 103</td>
<td>2100</td>
<td>45</td>
<td>2.3</td>
<td>1.8</td>
</tr>
</tbody>
</table>

The maximum predicted conventional tilt for the Drainage Line 7 is 45 mm/m (i.e. 4.5 %, or 1 in 22). The maximum predicted conventional curvatures are 2.3 km⁻¹ hogging and 1.8 km⁻¹ sagging, which equate to minimum radii of curvature of 0.43 km and 0.56 km, respectively. The predicted conventional strains for the Drainage Line 7 (based on 10 times the curvature) are 23 mm/m tensile and 18 mm/m compressive. The drainage line could also experience higher strains due to non-conventional ground movements. The distribution of strain along linear features shown in Fig. 4.4 includes those resulting from both conventional and non-conventional anomalous movements.

It is also possible that the drainage lines could experience some valley related movements resulting from the extraction of Longwalls 101 to 103, however these movements should be small due to reduced ground stresses resulting from the presence of adjoining open cut pits. It is also noted that the magnitudes of these uplift and closure movements are expected to be much lower than the conventional movements and hence may not be significant.

### 5.3.3. Comparison of the Predictions for Drainage Line 7

The comparison of the maximum predicted subsidence parameters for Drainage Line 7, resulting from the extraction of Longwalls 101 to 103, with those based on the Approved Layout is provided in Table 5.2. The values are the maxima along the section of the drainage line located within the Study Area.

### Table 5.2 Comparison of Maximum Predicted Conventional Subsidence Parameters for Drainage Line 7 based on the Approved Layout and the Extraction Plan Layout

<table>
<thead>
<tr>
<th>Layout</th>
<th>Maximum Predicted Total Conventional Subsidence (mm)</th>
<th>Maximum Predicted Total Conventional Tilt (mm/m)</th>
<th>Maximum Predicted Total Hogging Curvature (km⁻¹)</th>
<th>Maximum Predicted Total Sagging Curvature (km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approved Layout (101-103) (Report No. MSEC731)</td>
<td>2100</td>
<td>45</td>
<td>2.3</td>
<td>1.8</td>
</tr>
<tr>
<td>Extraction Plan Layout (Report No. MSEC867)</td>
<td>2100</td>
<td>45</td>
<td>2.3</td>
<td>1.8</td>
</tr>
</tbody>
</table>

The maximum predicted total subsidence parameters for Drainage Line 7 based on the Approved Layout are the same as those for the Extraction Plan Layout for Longwalls 101 to 103. The maximum predicted total subsidence parameters for the other drainage lines based on the Approved Layout are also the same as those for the Extraction Plan Layout for Longwalls 101 to 103 as discussed in Section 4.3.
5.3.4. Impact Assessments and Recommendations for the Drainage Lines

The maximum predicted total subsidence parameters for the drainage lines based on the Approved Layout are the same as those for the Extraction Plan Layout for Longwalls 101 to 103. The potential impacts for the drainage lines, based on the Extraction Plan Layout, therefore, are the same as those assessed based on the Approved Layout. The following summary outlines the potential impacts to the drainage lines provided in the report MSEC731:

- The drainage lines within the Study Area are ephemeral as water only flows during and for short periods after each rain event. Ponding naturally develops along some sections of the drainage lines, for short periods of time, after major rain events. Additional ponding may occur along the drainage lines resulting from the extraction of Longwalls 101 to 103.
- Sections of beds downstream of the additional ponding areas, may erode during subsequent rain events, especially during times of high flow. It is expected that, over time, the gradients along the drainage lines would approach grades similar to those that existed before mining. The extent of additional ponding along the drainage lines would, therefore, be expected to decrease with time.
- Fracturing and dilation of the bedrock would occur as a result of the extraction of these longwalls.
- In times of heavy rainfall, the majority of the surface water runoff would be expected to flow over the surface cracking in the beds and only a small proportion of the flow would be diverted into the fractured and dilated strata below. In times of low flow, however, a larger proportion of the surface water flow could be diverted into the strata below the beds and this could affect the quality and quantity of this water flowing through the cracked strata beds. Nevertheless, during high flow or low flow times, this small quantity is expected to have little impact on the overall quality of water flowing out of the drainage lines.

It is recommended that the drainage lines are visually monitored as the longwalls mine beneath them. It is recommended that management strategies are developed for the drainage lines, such that the impacts can be identified and remediated, as and if they are required.

5.4. Cliffs and Overhangs

5.4.1. Descriptions of the Cliffs

A total of six cliffs were identified within the UG1 Study Area. The locations of the identified cliffs are shown in Drawing No. MSEC867-08. Three of the cliffs, C2, C3 and C4, are located within the footprint of the approved out-of-pit emplacement (and will therefore be covered before the underlying Longwalls 104 and 105 are extracted) and one cliff, C1, is located outside of the Study Area. Hence revised subsidence predictions are not provided for these four cliffs. Two cliffs, C5 and C6, are located within the Study Area. Details of the cliffs are provided in Table 5.3

Table 5.3 Summary of Cliffs located within the Study Area

<table>
<thead>
<tr>
<th>ID</th>
<th>Approximate Overall Length (m)</th>
<th>Approximate Maximum Height (m)</th>
<th>Approximate Maximum Overhang (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>20</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>C6</td>
<td>20</td>
<td>10</td>
<td>0</td>
</tr>
</tbody>
</table>

5.4.2. Predictions for the Cliffs

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the cliffs, resulting from the extraction of Longwalls 101 to 103 for the Extraction Plan Layout, is provided in Table 5.4. The predicted tilts provided in this table are the maxima after the completion of all the longwalls. The predicted curvatures are the maxima at any time during or after the extraction of the longwalls.

Table 5.4 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Cliffs within the Study Area Resulting from the Extraction of Longwalls 101 to 103

<table>
<thead>
<tr>
<th>ID</th>
<th>Maximum Predicted Total Conventional Subsidence (mm)</th>
<th>Maximum Predicted Total Conventional Tilt (mm/m)</th>
<th>Maximum Predicted Total Conventional Hogging Curvature (km⁻¹)</th>
<th>Maximum Predicted Total Conventional Sagging Curvature (km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>2100</td>
<td>19</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>C6</td>
<td>2000</td>
<td>28</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
</tbody>
</table>
The predicted strains for the cliffs are provided in Table 5.5. The values have been provided for conventional movements (based on 10 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4). It is noted that the predicted conventional strains are greater than the predicted 95 and 99% confidence levels for the strains that include non-conventional movements, as the irregular strains are isolated and extreme events.

Table 5.5 Predicted Strains for the Cliffs based on Conventional and Non-Conventional Anomalous Movements

<table>
<thead>
<tr>
<th>Type</th>
<th>Conventional based on 10 times Curvature</th>
<th>Non-conventional based on the 95% Confidence Level</th>
<th>Non-conventional based on the 99% Confidence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tension</td>
<td>&gt; 30</td>
<td>10</td>
<td>22</td>
</tr>
<tr>
<td>Compression</td>
<td>&gt; 30</td>
<td>13</td>
<td>31</td>
</tr>
</tbody>
</table>

5.4.3. Comparison of the Predictions for the Cliffs

The comparison of the maximum predicted subsidence parameters for the cliffs within the Study Area, resulting from the extraction of Longwalls 101 to 103, with those based on the Approved Layout is provided in Table 5.6.

Table 5.6 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Cliffs based on the Extraction Plan Layout and the Approved Layout

<table>
<thead>
<tr>
<th>Layout</th>
<th>Maximum Predicted Total Conventional Subsidence (mm)</th>
<th>Maximum Predicted Total Conventional Tilt (mm/m)</th>
<th>Maximum Predicted Total Conventional Hogging Curvature (km⁻¹)</th>
<th>Maximum Predicted Total Conventional Sagging Curvature (km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approved Layout (LW101-103)</td>
<td>2100</td>
<td>28</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>(Report No. MSEC731)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extraction Plan Layout</td>
<td>2100</td>
<td>28</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>(Report No. MSEC867)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It can be seen from Table 5.6, that the maximum predicted conventional subsidence, tilt and curvature for the cliffs, based on the Extraction Plan Layout, are the same as the maxima based on the Approved Layout.

5.4.4. Impact Assessments and Recommendations for the Cliffs

The maximum predicted total subsidence parameters for the cliffs based on the Approved Layout are the same as those for the Extraction Plan Layout for Longwalls 101 to 103. The potential impacts for the cliffs, based on the Extraction Plan Layout, therefore, are the same as those assessed based on the Approved Layout. The following summary outlines the potential impacts to the cliffs lines provided in the report MSEC731:

- rock falls can be expected at these cliff lines;
- minor impacts are expected to Cliff C5 and C6; and
- cliff instabilities could occur on up to approximately 15% of the length of the exposed cliffs.

It should be recognised that it is extremely difficult to assess the likelihood of mining induced cliff instabilities based upon the predicted ground movements alone. The likelihood of a particular cliff becoming unstable naturally, i.e. without the effects of mining induced ground movements, is dependent on many factors, including the existing vertical and horizontal jointing, inclusions or weaknesses within the rock mass, the height, extent of undercutting, the length and orientation of the particular cliff with respect to the valley and the water pressure and seepage flow behind the rock face.

It is recommended, that persons who enter the area in the vicinity of the cliffs are made aware of the potential for rockfalls resulting from the extraction of the longwalls by appropriate signs and temporary fencing. Management strategies should be developed to ensure the safety of people that may be within the vicinity of the cliffs during the mining period.

The baseline condition of cliffs C5 and C6 should be documented and photographed prior to mining. The cliffs should be visually monitored during the mining period from a remote and safe location until such time that the mine subsidence movements have ceased.
5.5. **Rock Ledges**

There are rock ledges, also called rock outcrops and minor cliffs, located across the Study Area. The rock ledges are likely to experience the full range of predicted subsidence movements, as summarised in Table 4.1 and Table 4.2. The maximum predicted subsidence parameters for the rock ledges, based on the Extraction Plan Layout, therefore, are similar to the maxima based on the Approved Layout, as summarised in Table 4.3.

The potential impacts on the rock ledges, based on the Extraction Plan Layout, therefore, are the same as those assessed based on the Approved Layout, specifically, the potential for fracturing of sandstone and subsequent rockfalls, particularly where the rocks ledges are marginally stable. It is expected that occasional rockfalls or fracturing would not impact more than 5% of the total face area of rock ledges and overhangs in the Study Area.

It is recommended that management strategies are put in place to ensure the safety of people that may be within the vicinity of these rock ledges and overhangs during the mining period. Visual monitoring of the exposed rock ledges within the Study Area that are easily inspected should be undertaken during the mining period.

5.6. **Steep Slopes**

The locations of steep slopes are shown on Drawing No. MSEC867-08. The steep slopes within the Study Area could experience the full range of predicted subsidence movements, as summarised in Table 4.1 and Table 4.2. The maximum predicted subsidence parameters for the steep slopes, based on the Extraction Plan Layout, therefore, are similar to the maxima based on the Approved Layout, as summarised in Table 4.3.

The potential impacts on the steep slopes, based on the Extraction Plan Layout, therefore, are the same as those assessed based on the Approved Layout. The potential for ground surface cracking, is discussed in Section 4.9.

It has been observed that down slope movements occur on slopes that are located over or near extracted longwalls. Sometimes these movements are observed to be directed down the hill slope rather than towards the extracted goaf area. Where such movements occur on steep slopes, there is a higher likelihood that surface tension cracking can occur near the tops of the slopes. It is unlikely that mine subsidence would result in large-scale slope failure, since such failures have not been observed elsewhere as the result of longwall mining. It is expected that surface tension cracking and with careful management of remediation activities, it is thought the total would not impact more than 5% of the total face area of steep slopes in the Study Area.

It is recommended that the steep slopes are monitored throughout the mining period. Any significant surface cracking should be remediated by infilling with soil or other suitable materials, or by locally regrading and compacting the surface. Management strategies should be developed, to ensure that the steep slopes are maintained throughout the mining period.

5.7. **Threatened, Protected Species or Critical Habitats**

An investigation of the flora and fauna within the Study Area was undertaken by Ecological Australia (2017). Flora and fauna surveys within these areas were undertaken and did not identify any threatened flora species under the *Threatened Species Conservation Act, 1995*. There is known and potential habitat for a number of threatened fauna species within the Study Area as described in Ecological Australia (2017).

There is no change in subsidence impacts expected to threatened flora or fauna species based on the Extraction Plan Layout.

The effects of subsidence on flora and fauna within the Study Area are considered by Ecological Australia (2017).

Endangered Ecological Communities (EEC) are located within the Study Area and are discussed below in Section 5.8.

5.8. **Endangered Ecological Communities**

5.8.1. **Descriptions of the EECs**

A vegetation validation exercise was undertaken by Eco Logical in 2016 (Eco Logical, 2016) within the Study Area. The purpose of the survey was to revise existing vegetation mapping to confirm the extent of previously recorded vegetation communities, specifically targeting any endangered ecological communities present.
The vegetation validation exercise confirmed the presence of the two previously identified endangered ecological communities known as White Box Yellow Box Blakely’s Redgum Woodland and Derived Native Grasslands and Central Hunter Grey Box – Ironbark Woodland in the NSW North Coast and Sydney Basin Bioregions located within the Study Area as shown on Drawing No. MSEC867-08. In addition to the above, Eco Logical (2016) also identified Central Hunter Valley Eucalypt Forest and Woodland, listed as a CEEC under the EPBC Act. This CEEC was listed in May 2015 and does not apply to the approved Stage 1 and Stage 2 mining operations pursuant to section 158A of the EPBC Act.

The effects of subsidence on flora and fauna within the Study Area are considered by Ecological Australia (2017).

5.8.2. Predictions for the EECs

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the EECs, resulting from the extraction of Longwalls 101 to 103 for the Extraction Plan Layout, is provided in Table 5.7. The values are the maximum predicted parameters within 20 m of the perimeter of the EECs. The predicted tilts provided in this table are the maxima after the completion of all the longwalls. The predicted curvatures are the maxima at any time during or after the extraction of the longwalls.

<table>
<thead>
<tr>
<th>ID</th>
<th>Maximum Predicted Total Conventional Subsidence (mm)</th>
<th>Maximum Predicted Total Conventional Tilt (mm/m)</th>
<th>Maximum Predicted Total Conventional Hogging Curvature (km⁻¹)</th>
<th>Maximum Predicted Total Conventional Sagging Curvature (km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEC01</td>
<td>2250</td>
<td>50</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>EEC05</td>
<td>2050</td>
<td>55</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>EEC09</td>
<td>2200</td>
<td>55</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>EEC11</td>
<td>2250</td>
<td>40</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>EEC12</td>
<td>1000</td>
<td>55</td>
<td>2.7</td>
<td>1.6</td>
</tr>
<tr>
<td>EEC13</td>
<td>65</td>
<td>3</td>
<td>0.25</td>
<td>0.1</td>
</tr>
</tbody>
</table>

The predicted strains for the EECs are provided in Table 5.8. The values have been provided for conventional movements (based on 10 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4).

<table>
<thead>
<tr>
<th>Type</th>
<th>Conventional based on 10 times Curvature</th>
<th>Non-conventional based on the 95 % Confidence Level</th>
<th>Non-conventional based on the 99 % Confidence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tension</td>
<td>&gt; 30</td>
<td>10</td>
<td>22</td>
</tr>
<tr>
<td>Compression</td>
<td>&gt; 30</td>
<td>13</td>
<td>31</td>
</tr>
</tbody>
</table>

It is noted that the predicted conventional strains are greater than the predicted 95 and 99 % confidence levels for the strains that include non-conventional movements, as the irregular strains are isolated and extreme events.

5.8.3. Comparison of the Predictions for the EECs

The comparison of the maximum predicted subsidence parameters for the EECs within the Study Area, resulting from the extraction of Longwalls 101 to 103, with those based on the Approved Layout is provided in Table 5.9.
Table 5.9  Comparison of Maximum Predicted Conventional Subsidence Parameters for the EECs based on the Extraction Plan Layout and the Approved Layout

<table>
<thead>
<tr>
<th>Layout</th>
<th>Maximum Predicted Total Conventional Subsidence (mm)</th>
<th>Maximum Predicted Total Conventional Tilt (mm/m)</th>
<th>Maximum Predicted Total Conventional Hogging Curvature (km⁻¹)</th>
<th>Maximum Predicted Total Conventional Sagging Curvature (km⁻¹)</th>
</tr>
</thead>
</table>
| Approved Layout  
(Report No. MSEC731) | 2300 | > 100 | > 3 | > 3 |
| Extraction Plan Layout  
(Report No. MSEC867) | 2250 | 55 | > 3 | > 3 |

It can be seen from Table 5.9, that the maximum predicted conventional subsidence, tilt and curvature for the EECs, based on the Extraction Plan Layout, are the same as or lower than the maxima based on the Approved Layout.

### 5.8.4. Impact Assessments and Recommendations for the EECs

The maximum predicted total subsidence parameters for the EECs based on the Extraction Plan Layout are the same as or lower than those for the Approved Layout for Longwalls 101 to 103. The potential impacts for the EECs, based on the Extraction Plan Layout, therefore, are the same as or lower than those assessed based on the Approved Layout. The following summary outlines the potential impacts to the EECs provided in the report MSEC731:

- The likely changes in gradients will result in reduced grades and increased grades depending on the position of the EECs in the subsidence bowl. These changes in grade may result in ponding of surface water runoff where existing natural grades are relatively shallow.

- It is expected that fracturing and dilation of the bedrock would occur as a result of the extraction of Longwalls 101 to 103. It is possible that below some of the EECs, massive basalt layers could be present that could resist the deformation and cracking that occurs in the sandstone layers. Fracturing and dilation of the bedrock could result in surface cracking, as described in Section 4.9.

- It is expected, that the surface cracking could be easily and quickly remediated, if it is required, by infilling with soil or other suitable materials, or by locally regrading and compacting the surface.

It is recommended that the EECs are visually monitored after the proposed UG1 longwalls mine beneath them so that the impacts can be identified and remediated, if required. With remediation measures in place, potential impacts to EECs are predicted to be negligible (Ecological, 2017).

### 5.9. Natural Vegetation

Natural vegetation covers the majority of the Study Area. The natural vegetation could, therefore, experience the full range of predicted subsidence movements, as summarised in Table 4.1 and Table 4.2. The maximum predicted subsidence parameters for the natural vegetation, based on the Extraction Plan Layout, therefore, are the same as the maxima based on the Approved Layout, as summarised in Table 4.3.

The potential impacts on the natural vegetation, based on the Extraction Plan Layout, therefore, are the same as those assessed based on the Approved Layout.

### 5.10. Areas of Significant Geological Interest

A brief description of the geology within the Study Area is provided in Section 1.4. A discussion of alluvial/regolith palaeochannel deposits to the north east of the Study Area is provided in Section 4.6.1.
The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the public utilities located within the Study Area for Longwalls 101 to 103. The predicted parameters for each of the built features have been compared to the predicted parameters based on the Approved Layout.

As listed in Table 2.1, the following public utilities were not identified within the Study Area nor in the immediate surrounds:

- Tunnels;
- Liquid Fuel Pipelines;
- Gas pipelines;
- Liquid fuel pipelines;
- Water and sewage treatment works;
- Dams, Reservoirs or Associated works; and
- Air strips.

### 6.1. Railways

The Sandy Hollow – Gulgong Railway Line is located to the north and east of Longwalls 101 to 103 as shown in Drawing No. MSEC867-10.

The nearest edges of Longwalls 101 to 103 to the Sandy Hollow – Gulgong Railway Line vary from approximately 380 m to 470 m. At these locations the depths of cover range from 110 to 130 m and, hence, these distances between the edges of the mined panels and the railway are equivalent to 3.5 to 3.6 times the depths of cover.

The distances to the railway line based on the Extraction Plan layout are slightly greater than those for the Approved Layout. Therefore, the predictions and impact assessments based on the Extraction Plan Layout are the similar to or less than those for the Approved Layout. A discussion of the predicted subsidence movements and impact assessments from MSEC731 is provided below.

As detailed in Section 1.4.1, there are palaeochannel deposits, with a maximum thickness of 40-50 m, to the north and east of the proposed UG1 longwalls, where the depths of cover range from 90 to 130 m. Section 4.6.1 notes that the presence of a palaeochannel should result in less subsidence within these alluvial and unconsolidated sediment areas and reduced far-field movements beyond these channels at the railway track and transmission towers.

### 6.1.1. Predictions for the Sandy Hollow – Gulgong Railway Line

At distances of 380 m to 470 m between the longwalls and the railway track and based on these depths of cover, the rail track will not be subjected to measurable tilts, curvatures or strains; however, the railway line may experience far-field horizontal movements which are discussed in Section 3.3 and 4.6.

It should be noted that most of the monitored NSW far-field horizontal movement data were measured at sites in the Southern Coalfield where the depths of cover are approximately 500 m, and the depths of cover at UCM where high far-field horizontal movements were monitored were approximately 300 m, which are both much greater than the depths of cover near this railway line where the depth of cover ranges from 47 to 130 m.

Fig. 4.6 shows the upper limit of previously observed absolute far-field horizontal movements at UCM for the sites located 3.5 to 3.6 times the depths of cover from longwalls, was less than 75 mm. However this data includes the H-Line case and the F-Line case where high valley closure movements were observed. Ignoring sites with high valley closure movements and the multi seam cases, Fig. 4.6 shows the upper limit of previously observed absolute far-field horizontal movements for sites located 3.5 to 3.6 times the depths of cover from longwalls, is less than 60 mm.

As discussed above, the likely subsidence and far-field horizontal movements at the Sandy Hollow – Gulgong Railway are expected to be less than the normally predicted subsidence and far-field horizontal movements because of the presence of unconsolidated sediments in palaeochannels that are up to 50 m thick just outside the edges of the proposed longwall panels. These far-field horizontal movements generally do not result in impact at structures unless they are very sensitive to differential horizontal movements. The predicted far-field horizontal movements of less than 60 mm at the railway track are expected to be bodily movements that are directed across the track towards the extracted goaf area and should be accompanied by very low levels of strain.
The range of potential strains associated with non-conventional movements has been assessed using monitoring data from previously extracted panels in the NSW Coalfields, for single-seam conditions, where the width-to-depth ratios and extraction heights were similar to those of Longwalls 101 to 103.

The 95% confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining are 1.6 mm/m tensile and 1.5 mm/m compressive. The 99% confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining are 2.9 mm/m tensile and 3.0 mm/m compressive. The 75% confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining are 0.5 mm/m both tensile and compressive, which is the typical limit of accuracy of strain measurement by conventional survey methods. It is noted that these results comprise a component of survey tolerance and have also been affected by disturbed survey marks and survey errors.

6.1.2. Impact Assessment and Recommendations for the Sandy Hollow – Gulgong Railway Line

The Sandy Hollow – Gulgong Railway Line is located more than 380 m from Longwalls 101 to 103. The railway line is not expected to be subject to measurable conventional vertical subsidence, tilt, curvature or conventional strain. However, the railway may experience low level far-field horizontal movements. The upper limit of previously observed absolute far-field horizontal movements for sites located 3.5 to 3.6 times the depths of cover from longwalls, is in the order of 60 mm. The presence of unconsolidated sediments should result in reduced far-field movements at the railway line.

The existing open cut (OC1) would significantly reduce the potential for far-field movements to develop at features located beyond the open cut extent. The location of the railway line outside OC1 is greater than nine times the depth of cover from the longwalls and far-field horizontal movements would not be expected, even without the presence of OC1.

The predicted far-field horizontal movements of less than 60 mm at the railway track are expected to be bodily movements that are directed across the track towards the extracted goaf area and should be accompanied by very low levels of strain that are in the order of survey tolerance. If horizontal movement towards the longwalls develops along the alignment of the railway line, it is possible however, that a slight increase in compression could develop in the rail due to the curve around the Northern corner of Longwall 101. The horizontal movement along the straight sections of the railway line or with increasing distance from the extracted longwalls are unlikely to adversely impact on the railway line.

In order to manage the predicted impacts on ARTC infrastructure, it is recommended that a program of ground monitoring be implemented near the railway line for each longwall to check for the development of compression along the alignment of the rail and for possible anomalous movements, such as at the edges of the unconsolidated sediments. Monitoring and management strategies should be developed in consultation with ARTC. It is expected that the potential impacts on the ARTC infrastructure can be managed with the implementation of the necessary monitoring and management strategies.

6.2. Roads

6.2.1. Descriptions of the Roads

The locations of the roads owned by Mid Western Regional Council (MWRC) are shown in Drawing No. MSEC867-09. The roads in the vicinity of Longwalls 101 to 103 include:

- Ulan Road;
- Ulan Road bridge (over the Sandy Hollow – Gulgong Railway);
- publicly accessible sections of Ulan-Wollar Road (on land owned by MWRC and on land owned by MCO);
- publicly inaccessible (i.e. closed) sections of Ulan-Wollar Road (on land owned by MWRC); and
- other roads closed to the public (on land owned by MWRC) including Murragamba Road and Carrs Gap Road.

MWRC also own infrastructure associated with these roads, such as the road pavement, embankments, tunnels and culverts.

The current route of Ulan-Wollar Road from the intersection with Ulan Road and around the northern end of Longwalls 101 to 103 has been realigned as shown in Drawing No. MSEC867-09 by construction of a new road pavement. The former road alignment (located closer to the northern ends of Longwalls 101 to 103 on MWRC owned land) has been closed to the public at both ends. It is understood these changes to the Ulan-Wollar Road alignment are under application to be officially gazetted and at this stage, the realigned section of the public road is located on land owned by Moolarben Coal Operations. Other closed roads include the unsealed roads Murragamba Road and Carrs Gap Road as shown in Drawing No. MSEC867-09 which are located on MWRC owned land.
Ulan Road is located to the north west of Longwalls 101 to 103, more than 1 km from the nearest longwall with an open cut pit between the road and the longwalls. A road bridge is located along Ulan Road, over the Sandy Hollow – Gulgong Railway line, and is 1.2 km from Longwall 101.

The nearest publicly accessible sections of Ulan-Wollar Road to the longwalls are approximately 250 m from Longwall 101 and 335 m from Longwall 103. At these locations the depths of cover range from 110 m to 130 m and at the minimum distance of 250 m the road is 1.9 times the depth of cover from the longwalls.

The nearest closed sections of Ulan-Wollar Road are approximately 100 m from Longwall 103. Additionally, sections of the other closed roads, Murragamba Road and Carrs Gap Road, directly overly Longwalls 101 to 103. As these roads are closed to the public, detailed subsidence predictions have not been provided.

Ulan-Wollar Road is a sealed bitumen pavement with no kerb and gutter. The nearest drainage culvert is located approximately 1.2 km to the south east at Murragamba Creek. An embankment and twin tunnels have also been constructed beneath the road along the alignment of the conveyor, at 720 m from Longwall 101.

6.2.2. Predictions for the Roads

At distances of 250 m or more between the longwalls and the publicly accessible sections of Ulan-Wollar Road and based on depths of cover of 110 m to 130 m, Ulan-Wollar Road will not be subjected to measurable conventional mine subsidence ground movements (i.e. less than limits of survey accuracy); however, the road may experience far-field horizontal movements which are discussed below. Ulan Road is located 1 km or more from Longwall 101 and is separated from the longwalls by the open cut pit. Ulan Road will not be subjected to measurable conventional mine subsidence ground movements (i.e. less than limits of survey accuracy) and far-field horizontal movements are not expected due to the distance from the longwalls and the presence of the open cut pit, which is discussed in Section 4.6.2.

Previously observed absolute far-field horizontal movements from Fig. 4.6 show the upper limit at Ulan Coal Mine for the sites located 1.9 times the depths of cover from longwalls, was less than 130 mm, (however this data includes the H-Line case and the F-Line case where high valley closure movements were observed). Ignoring sites with high valley closure movements and the multi seam cases, Fig. 4.6 shows the upper limit of previously observed absolute far-field horizontal movements for sites located 1.9 times the depths of cover from longwalls, is less than 80 mm.

Ulan Road is located over nine times the depth of cover from Longwall 101 and, based on Fig. 4.6, is not expected to experience far-field horizontal movements.

Ulan-Wollar Road, therefore, is predicted to experience incremental far-field horizontal movements in the order of 80 mm due to the extraction of each of Longwalls 101 to 103. These low level horizontal movements are not expected to be associated with measurable tilts, curvatures or strains. The estimated far-field horizontal movements may be conservative due to the presence of the palaeochannel as discussed in Section 4.6.1.

The maximum observed strains from Section 4.4.1 at distances between 200 m and 600 m from the nearest longwall goaf edge are 1.6 mm/m tensile and 1.5 mm/m compressive based on the 95 % confidence level and 2.9 mm/m tensile and 3.0 mm/m compressive based on the 99 % confidence level. The 75 % confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining are 0.5 mm/m both tensile and compressive, which is the typical limit of accuracy of strain measurement by conventional survey methods. It is noted that these results comprise a component of survey tolerance and have also been affected by disturbed survey marks and survey errors.

6.2.3. Impact Assessments and Recommendations for the Roads

The Ulan-Wollar Road conveyor tunnels and embankment, and the culvert at Murragamba Creek are located about six and nine times the depth of cover respectively from the longwalls and far-field horizontal movements would not be expected at this distance. Similarly, Ulan Road and the bridge over the Sandy Hollow-Gulgong Railway are located beyond OC1 at greater than nine times the depth of cover from the longwalls and far-field horizontal movements would not be expected at this distance, even without the presence of OC1. Adverse impacts to these features resulting from the extraction of Longwalls 101 to 103 are considered to be unlikely to occur.

The predicted far-field horizontal movements of less than 80 mm at the road are expected to be bodily movements that are directed across the general alignment of the road towards the extracted goaf area and should be accompanied by very low levels of strain that are in the order of survey tolerance.

There is the potential for measurable ground strains to occur resulting from non-conventional movements. The statistical analysis of observed strain data between 200 m and 600 m from extracted longwalls shows a 25% probability of exceedance of 0.5 mm/m tensile and compressive, and a 5% probability of exceedance of approximately 1.5 mm/m tensile and compressive.
With the publicly accessible sections of Ulan-Wollar Road located 250 m or more from Longwalls 101 to 103 and the low probability of significant observed strains developing based on statistical analysis, the development of adverse impacts to the road due to the extraction of Longwalls 101 to 103 is considered to be unlikely to occur.

Ground monitoring and visual monitoring is recommended for Ulan-Wollar Road for each longwall to check for the potential development of irregular subsidence movements.

It is expected that the potential impacts on the MWRC infrastructure can be managed with the implementation of the necessary monitoring and management strategies.

6.3. Four Wheel Drive Tracks

There are also a number of four wheel drive tracks through the Study Area, one of which is shown on Drawing No. MSEC867-09 above the south western end of Longwall 103. These tracks are not publicly accessible.

The tracks could experience the full range of predicted subsidence movements, as summarised in Table 4.1 and Table 4.2. The maximum predicted subsidence parameters for these tracks, based on the Extraction Plan Layout, therefore, are the same as the maxima based on the Approved Layout, as summarised in Table 4.3.

The potential impacts on the tracks, based on the Extraction Plan Layout, therefore, are the same as those assessed based on the Approved Layout. Impacts are expected to include cracking, stepping and rippling of the road surfaces. The tracks may also experience ponding, however, the impacts of increased levels of ponding along these roads can be remediated by regrading and relevelling the roads using standard road maintenance techniques.

6.4. Road Drainage Culverts

No drainage culverts were identified within the Study Area; however, drainage culverts are located along Ulan-Wollar Road and the Sandy Hollow – Gulgong Railway, the nearest of which are at the Murragamba Creek crossings, over 1.2 km from Longwall 103.

At this distance the culverts would not be subjected to measurable conventional mine subsidence ground movements. The culverts are located about six and nine times the depth of cover respectively from the longwalls and far-field horizontal movements would not be expected at this distance. Adverse impacts to these culverts resulting from the extraction of Longwalls 101 to 103 are considered to be unlikely to occur. Should impacts occur, they are expected to be isolated and of a minor nature and readily repairable.

6.5. Electrical Infrastructure

6.5.1. Descriptions of the Electrical Infrastructure

The locations of the electrical infrastructure within the vicinity of Longwalls 101 to 103 are shown in Drawing No. MSEC867-09.

A 66kV powerline owned by Essential Energy is located along the general alignment of Ulan-Wollar Road and Sandy Hollow – Gulgong Railway. At changes in the alignment of the 66kV powerline, the timber poles have guy wires for additional lateral restraint. A substation is also proposed to the north of Longwall 101.

The nearest sections of the 66kV powerline to the longwalls are approximately 90 m from the finishing (northern) end of Longwall 103 (pole 70548) and 230 m from Longwall 101 (pole 70540). At these locations, the depths of cover range from 110 m to 130 m and, at the minimum distance of 90 m, the 66kV powerline is 0.7 times the depth of cover from the longwall. At 230 m from Longwall 101, the 66kV powerline is 1.8 times the depth of cover from the longwall.

A 330kV electricity transmission line owned by TransGrid is located to the north of the Study Area. The transmission tower locations and reference numbers are shown in Drawing No. MSEC867-09. There are ten towers that are located within 1 km of Longwalls 101 to 103. The distances of these towers from the nearest longwall, are summarised in Table 6.1. Pictures of the tension and suspension towers are shown in Fig. 6.1. Depths of cover at the nearest longwalls vary from about 110 m to 140 m.
### Table 6.1 Distances of the 330 kV Transmission Towers from Longwalls 101 to 103

<table>
<thead>
<tr>
<th>Tower Number</th>
<th>Nearest Longwall</th>
<th>Tower Type</th>
<th>Distance of the Transmission Towers Centrelines from the Nearest Longwall (m)</th>
<th>Distance divided by depth of cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>102</td>
<td>103</td>
<td>Suspension</td>
<td>960</td>
<td>8.7</td>
</tr>
<tr>
<td>103</td>
<td>103</td>
<td>Suspension</td>
<td>690</td>
<td>6.3</td>
</tr>
<tr>
<td>104</td>
<td>103</td>
<td>Suspension</td>
<td>650</td>
<td>5.9</td>
</tr>
<tr>
<td>105</td>
<td>102</td>
<td>Suspension</td>
<td>635</td>
<td>5.3</td>
</tr>
<tr>
<td>106</td>
<td>101</td>
<td>Tension</td>
<td>620</td>
<td>4.8</td>
</tr>
<tr>
<td>107</td>
<td>101</td>
<td>Suspension</td>
<td>390</td>
<td>3.0</td>
</tr>
<tr>
<td>108</td>
<td>101</td>
<td>Suspension</td>
<td>340</td>
<td>2.6</td>
</tr>
<tr>
<td>109</td>
<td>101</td>
<td>Suspension</td>
<td>550</td>
<td>4.2</td>
</tr>
<tr>
<td>110</td>
<td>101</td>
<td>Tension</td>
<td>765</td>
<td>5.9</td>
</tr>
<tr>
<td>111</td>
<td>101</td>
<td>Suspension</td>
<td>910</td>
<td>7.0</td>
</tr>
</tbody>
</table>

![Fig. 6.1 Photograph of a 330 kV Suspension Tower (Left) and Tension Tower (Right)](image)

#### 6.5.2. Predictions for the 66kV Powerline

At distances of 90 m or more from the longwalls, the 66kV powerline and substation are outside the predicted 20 mm subsidence contour. The predicted subsidence movements at the 66kV powerline and substation are therefore less than typical limits of measurable conventional mine subsidence ground movements (i.e. less than limits of survey accuracy); however, the 66kV powerline and substation may experience far-field horizontal movements.

Previously observed absolute far-field horizontal movements from Fig. 4.6 show the upper limit of previously observed absolute far-field horizontal movements (ignoring multi seam cases) for the sites located 0.7 times the depths of cover from longwalls, was less than 180 mm. At 1.8 times the depths of cover from longwalls, the upper limit of previously observed absolute far-field horizontal movements was less than 130 mm. These limits include data from the H-Line case and the F-Line case where high valley closure movements were observed. Ignoring sites with high valley closure movements and the multi seam cases, Fig. 4.6 shows the upper limit of previously observed absolute far-field horizontal movements for sites located 0.7 times and 1.8 times the depths of cover from longwalls, is less than 155 mm and 90 mm respectively.

The 66kV powerline and substation, therefore, are predicted to experience incremental far-field horizontal movements in the order of 90 mm to 155 mm due to the extraction of each of Longwalls 101 to 103. These horizontal movements are not expected to be associated with measurable tilts, curvatures or strains. The estimated far-field horizontal movements may be conservative due to the presence of the palaeochannel as discussed in Section 4.6.1.
The maximum observed strains from Section 4.4.1 at distances within 200 m of the nearest longwall goaf edge are 3.3 mm/m tensile and 3.0 mm/m compressive based on the 95% confidence level and 9.2 mm/m tensile and 14.4 mm/m compressive based on the 99% confidence level. The 75% confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining are 0.9 mm/m tensile and 0.5 mm/m compressive. It is noted that these results comprise a component of survey tolerance and have also been affected by disturbed survey marks and survey errors.

6.5.3. Predictions for the 330 kV Electricity Transmission Line

At distances of 340 m or more between the longwalls and the transmission line towers and based on depths of cover of 110 m to 130 m, the towers will not be subjected to measurable conventional mine subsidence ground movements (i.e. less than limits of survey accuracy); however, the towers may experience far-field horizontal movements.

The shortest distance from the towers to the longwalls is 340 m, from tower 108. This equates to approximately 2.6 times the depth of cover from the longwalls. Fig. 4.6 shows the upper limit of previously observed absolute far-field horizontal movements at Ulan Coal Mine for the sites located 2.6 times the depths of cover from longwalls, was less than 105 mm, (however this data includes the H-Line case and the F-Line case where high valley closure movements were observed). Ignoring sites with high valley closure movements and the multi seam cases, Fig. 4.6 shows the upper limit of previously observed absolute far-field horizontal movements for sites located 2.6 times the depths of cover from longwalls, is less than 70 mm.

The transmission line, therefore, is predicted to experience maximum incremental far-field horizontal movements in the order of 70 mm due to the extraction of each of Longwalls 101 to 103. These low level horizontal movements are not expected to be associated with measurable tilts, curvatures or strains. The estimated far-field horizontal movements may be conservative due to the presence of the palaeochannel as discussed in Section 4.6.1.

The maximum observed strains from Section 4.4.1 at distances between 200 m and 600 m from the nearest longwall goaf edge are 1.6 mm/m tensile and 1.5 mm/m compressive based on the 95% confidence level and 2.9 mm/m tensile and 3.0 mm/m compressive based on the 99% confidence level. The 75% confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining are 0.5 mm/m both tensile and compressive, which is the typical limit of accuracy of strain measurement by conventional survey methods. It is noted that these results comprise a component of survey tolerance and have also been affected by disturbed survey marks and survey errors.

6.5.4. Impact Assessments and Recommendations for the Electrical Infrastructure

The maximum predicted total subsidence parameters for the electrical infrastructure based on the Extraction Plan Layout are the same as or less than those for the Approved Layout for Longwalls 101 to 103. The potential impacts for the electrical infrastructure, based on the Extraction Plan Layout, therefore, are the same as or lower than those assessed based on the Approved Layout.

The existing open cut (OC1) would significantly reduce the potential for far-field movements to develop at features located beyond the open cut extent. The locations of the 66kV powerline and 330kV electricity transmission line outside OC1 are greater than nine times the depth of cover from the longwalls and far-field horizontal movements would not be expected, even without the presence of OC1.

66kV Powerline

The predicted subsidence movements at the 66kV powerline and substation are expected to be less than typical measurable limits for conventional vertical subsidence, tilt, curvature or strain. However, the 66kV powerline and substation may experience far-field horizontal movements. The upper limit of previously observed absolute far-field horizontal movements for sites located 0.7 times to 1.8 times the depths of cover from longwalls, is in the order of 90 mm to 155 mm. The presence of unconsolidated sediments should result in reduced far-field movements at the 66kV powerline and substation.

The predicted far-field horizontal movements at the 66kV powerline are expected to be bodily movements that are directed across the general alignment of the 66kV powerline towards the extracted goaf area and should be accompanied by very low levels of strain that are in the order of survey tolerance. Relative movement between poles is expected to be less than 50 mm. Negligible relative movement is expected to develop within the substation. Adverse impact to the 66kV powerline and the substation resulting from these potential far-field horizontal movements are considered to be unlikely to occur.

There is the potential for measurable ground strains to occur resulting from non-conventional movements. The statistical analysis of observed strain data within 200 m of extracted longwalls shows a 25% probability of exceedance of 0.9 mm/m tensile and 0.5 mm/m compressive, and a 5% probability of exceedance of 3.3 mm/m tensile and 3.0 mm/m compressive.
With the location of the 66kV powerline and substation outside the longwall footprint and the low probability of significant observed strains developing based on statistical analysis, the development of adverse impacts to the 66kV powerline and substation due to the extraction of Longwalls 101 to 103 is considered to be unlikely to occur.

The ground movements can be monitored using traditional survey lines and visual inspections. These monitoring methods can be used to identify the development of irregular ground movements.

It is recommended that monitoring and management strategies are developed, in consultation with Essential Energy, to manage the 66kV powerline and substation for potential irregular ground movements. It is expected that the 66kV powerline and substation can be maintained in a safe and serviceable condition with the implementation of the appropriate monitoring and management strategies.

330 kV Electricity Transmission Line

The cables along the 330 kV transmission line are not directly affected by ground strains, as they are supported by the towers above ground level. The cables can, however, be affected by changes in bay lengths, i.e. the distances between the towers at the level of the cables, which result from mining induced differential subsidence, horizontal ground movements and lateral movements at the tops of the towers due to differential tilting of the towers. The stability of the transmission towers can be affected by the mining induced tilts, curvatures and ground strains at the tower locations and by changes in the catenary profiles of the cables.

The transmission towers are not expected to be subject to measurable conventional vertical subsidence, tilt, curvature or strain. It is unlikely, therefore, that the conventional movements would result in adverse impacts on the transmission line.

Far-field horizontal movements could result in small changes in the distances between the towers, particularly those located closest to the longwalls. With the alignment of the towers around the northern corner of the longwall layout, the predicted horizontal movements are expected to result in a net shortening of the distances between the towers. The towers located the furthest distances from the longwalls may experience minor net opening. The maximum predicted shortening is 50 mm, between towers 107 and 108. The predicted change in distance between the remaining towers due to far-field horizontal movements is less than 20 mm, which is the typical limit of survey accuracy. The predicted change in distance between the remaining towers is small since they are generally expected to move in the same direction towards the longwalls. It is also noted that the presence of unconsolidated sediments may result in reduced far-field movements and associated changes in distance between towers.

The 95 % confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining are 1.6 mm/m tensile and 1.5 mm/m compressive. The 99 % confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining are 2.9 mm/m tensile and 3.0 mm/m compressive. It is recommended that TransGrid review the structural integrity of the towers based on changes in the tower leg spacings (i.e. k-point distances) resulting from the above strains. The potential for non-conventional movements in the locations of the towers is very low, due to their distances from the longwalls, however, the potential for these irregular movements cannot be discounted.

It is recommended that strategies are developed, in consultation with TransGrid, to manage the potential for non-conventional movements at the transmission tower locations.

The management strategies should include monitoring of the transmission towers during active subsidence to identify the potential development of non-conventional ground movements between tower legs and the absolute positions of the towers.

It is expected that the potential impacts on the TransGrid 330kV transmission line can be managed with the implementation of the necessary monitoring and management strategies.

6.6. Telecommunications Infrastructure

6.6.1. Descriptions of the Telecommunications Infrastructure

The locations of the telecommunications infrastructure are shown in Drawing No. MSEC867-09.

The telecommunications infrastructure in the vicinity of Longwalls 101 to 103 comprises Telstra owned optical fibre and copper cables that roughly follow the alignment of Ulan Wollar Road and the Sandy Hollow – Gulgong Railway Line. There are no active telecommunication cables above Longwalls 101 to 103.

The telecommunication cables are located approximately 240 m to the north of Longwall 101 at their nearest point. To the east of this location, the cable distance from the ends of the longwalls is a maximum of 520 m (from Longwall 101) and a minimum of 335 m from Longwall 103. To the west, the cable distance from the longwall increases to greater than 1 km. At these locations the depths of cover range from 110 m
to 130 m and at the minimum distance of 240 m the cables are 1.8 times the depths of cover from the longwalls. The optical fibre cable is direct buried.

6.6.2. Predictions for the Telecommunications Infrastructure

At distances of 240 m or more between the longwalls and the telecommunications cables and based on depths of cover of 110 m to 130 m, the cables will not be subjected to measurable conventional mine subsidence ground movements (i.e. less than limits of survey accuracy); however, the cables may experience far-field horizontal movements.

Previously observed absolute far-field horizontal movements from Fig. 4.6 show the upper limit at Ulan Coal Mine for the sites located 1.8 times the depths of cover from longwalls, was less than 130 mm, (however this data includes the H-Line case and the F-Line case where high valley closure movements were observed). Ignoring sites with high valley closure movements and the multi seam cases, Fig. 4.6 shows the upper limit of previously observed absolute far-field horizontal movements for sites located 1.8 times the depths of cover from longwalls, is less than 80 mm.

The telecommunication cables, therefore, are predicted to experience incremental far-field horizontal movements in the order of 80 mm due to the extraction of each of Longwalls 101 to 103. These low level horizontal movements are not expected to be associated with measurable tilts, curvatures or strains. The estimated far-field horizontal movements may be conservative due to the presence of the palaeochannel as discussed in Section 4.6.1.

The maximum observed strains from Section 4.4.1 at distances between 200 m and 600 m from the nearest longwall goaf edge are 1.6 mm/m tensile and 1.5 mm/m compressive based on the 95 % confidence level and 2.9 mm/m tensile and 3.0 mm/m compressive based on the 99 % confidence level. The 75 % confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining are 0.5 mm/m both tensile and compressive, which is the typical limit of accuracy of strain measurement by conventional survey methods. It is noted that these results comprise a component of survey tolerance and have also been affected by disturbed survey marks and survey errors.

6.6.3. Impact Assessment and Recommendations for Telecommunications Cables

The optical fibre and copper cables are located 240 m or more from Longwalls 101 to 103. The cables are not expected to be subjected to measurable conventional vertical subsidence, tilt, curvature or strain. However, the cables may experience low level far-field horizontal movements. The upper limit of previously observed absolute far-field horizontal movements for sites located 1.8 times the depths of cover from longwalls, is in the order of 80 mm. The presence of unconsolidated sediments should result in reduced far-field movements at the cables.

The existing open cut (OC1) would significantly reduce the potential for far-field movements to develop at features located beyond the open cut extent. The location of the cables outside OC1 is greater than nine times the depth of cover from the longwalls and far-field horizontal movements would not be expected at this distance, even without the presence of OC1.

The predicted far-field horizontal movements of less than 80 mm at the cables are expected to be bodily movements that are directed across the general alignment of the cable towards the extracted goaf area and should be accompanied by very low levels of strain that are in the order of survey tolerance.

Copper telecommunications cables have been mined beneath extensively in NSW and are known to tolerate significant subsidence related movements without impact. The copper cable is located over 1.8 times the depth of cover from Longwalls 101 to 103 and at this distance the development of adverse impacts to the copper cable due to the extraction of Longwalls 101 to 103 is considered to be unlikely to occur.

The optical fibre cable is direct buried and, therefore, will not be impacted by the tilts resulting from the extraction of Longwalls 101 to 103. The cables may experience measurable ground strains resulting from non-conventional movements. The statistical analysis of observed strain data between 200 m and 600 m from extracted longwalls shows a 25 % probability of exceedance of 0.5 mm/m tensile and compressive, and a 5% probability of exceedance of approximately 1.5 mm/m tensile and compressive.

Tensile strains in the optical fibre cables can develop where the cables connect to the support structures, which may act as anchor points, preventing any differential movements that may have been allowed to occur within the ground. Tree roots have also been known to anchor cables to the ground. The extent to which the anchor points affect the ability of the cable to tolerate the mine subsidence movements depends on the cable size, type, age, installation method and ground conditions.

In addition to this, optical fibre cables contain additional fibre lengths over the sheath lengths, where the individual fibres are loosely contained within tubes. Compression of the sheaths can transfer to the loose
tubes and fibres and result in ‘micro-bending’ of the fibres constrained within the tubes, leading to higher attenuation of the transmitted signal.

With the location of the optical fibre cable at 240 m or more from Longwalls 101 to 103 and the low probability of significant observed strains developing based on statistical analysis, the development of adverse impacts to the optical fibre cable due to the extraction of Longwalls 101 to 103 is considered to be unlikely to occur.

The potential transfer of ground strain into the Telstra optical fibre cables can be monitored using Optical Time Domain Reflectometry (OTDR). The ground movements can also be monitored using traditional survey lines. These monitoring methods can be used to identify the development of irregular ground movements. If non-conventional movements or signal attenuation are detected during active subsidence, then the cable can be relieved by locally exposing and then reburying the affected section of cable.

It is recommended that monitoring and management strategies are developed, in consultation with Telstra, to manage the optical fibre cable for potential irregular ground movements. It is expected that the cable can be maintained in serviceable condition with the implementation of the appropriate monitoring and management strategies.
7.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE PUBLIC AMENITIES

As listed in Table 2.1, the following public amenities were not identified within the Study Area nor in the immediate surrounds:

- Hospitals;
- Places of worship;
- Schools;
- Shopping centres;
- Community centres;
- Office buildings;
- Swimming pools;
- Bowling greens;
- Ovals or cricket grounds;
- Racecourses;
- Golf courses; and
- Tennis courts.
8.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE FARM LAND AND FARM FACILITIES

The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the farm land and facilities located within the Study Area for Longwalls 101 to 103.

As listed in Table 2.1, the following farm land facilities were not identified within the Study Area nor in the immediate surrounds:

- Agricultural utilisation or agricultural suitability of farm land;
- Farm buildings or sheds;
- Tanks;
- Gas or fuel storages;
- Poultry sheds;
- Glass houses;
- Hydroponic systems;
- Irrigation systems; and
- Wells or Bores.

8.1. Fences

Fences are located within the Study Area and are constructed in a variety of ways, generally using either timber or metal materials.

The fences could experience the full range of predicted subsidence movements, as summarised in Table 4.1 and Table 4.2. The maximum predicted subsidence parameters for the fences, based on the Extraction Plan Layout, therefore, are the same as the maxima based on the Approved Layout, as summarised in Table 4.3.

Fences can be affected by tilting of the fence posts and by changes of tension in the fence wires due to strain as mining occurs. Fences are generally flexible in construction and can usually tolerate significant tilts and strains.

Any impacts on the fences are likely to be of a minor nature and relatively easy to remediate by re-tensioning fencing wire, straightening fence posts, and if necessary, replacing some sections of fencing.

It is recommended that management plans be developed to manage potential impacts on fences during the mining of the longwalls.

8.2. Farm Dams

8.2.1. Descriptions of the Farm Dams

The locations of the identified farm dams are shown in Drawing No. MSEC867-10. There is one farm dam (A02d03) within the Study Area. The farm dam is located near the sterilised coal block between LW102 A and B and is adjacent to the Longwall 103 tailgate.

This farm dam is located on land owned by MCO.

8.2.2. Predictions for the Farm Dams

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the farm dam, resulting from the extraction of Longwalls 101 to 103 for the Extraction Plan Layout, is provided in Table 8.1. The predicted tilts provided in this table are the maxima after the completion of all the longwalls. The predicted curvatures are the maxima at any time during or after the extraction of the longwalls.
Table 8.1  Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Farm Dam within the Study Area Resulting from the Extraction of Longwalls 101 to 103

<table>
<thead>
<tr>
<th>ID</th>
<th>Maximum Predicted Total Conventional Subsidence (mm)</th>
<th>Maximum Predicted Total Conventional Tilt (mm/m)</th>
<th>Maximum Predicted Total Conventional Hogging Curvature (km⁻¹)</th>
<th>Maximum Predicted Total Conventional Sagging Curvature (km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A02d03</td>
<td>180</td>
<td>3.0</td>
<td>0.15</td>
<td>0.02</td>
</tr>
</tbody>
</table>

The predicted strains for the farm dam are provided in Table 5.5. The values have been provided for conventional movements (based on 10 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4).  

Table 8.2  Predicted Strains for the Farm Dam based on Conventional and Non-Conventional Anomalous Movements

<table>
<thead>
<tr>
<th>Type</th>
<th>Conventional based on 10 times Curvature</th>
<th>Non-conventional based on the 95 % Confidence Level</th>
<th>Non-conventional based on the 99 % Confidence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tension</td>
<td>1.5</td>
<td>3.3</td>
<td>9.2</td>
</tr>
<tr>
<td>Compression</td>
<td>0.2</td>
<td>3.0</td>
<td>14.4</td>
</tr>
</tbody>
</table>

8.2.3.  Comparison of the Predictions for the Farm Dams

The comparison of the maximum predicted subsidence parameters for the farm dam within the Study Area, resulting from the extraction of Longwalls 101 to 103, with those based on the Approved Layout is provided in Table 8.3.

Table 8.3  Comparison of Maximum Predicted Conventional Subsidence Parameters for the Farm Dam based on the Extraction Plan Layout and the Approved Layout

<table>
<thead>
<tr>
<th>Layout</th>
<th>Maximum Predicted Total Conventional Subsidence (mm)</th>
<th>Maximum Predicted Total Conventional Tilt (mm/m)</th>
<th>Maximum Predicted Total Conventional Hogging Curvature (km⁻¹)</th>
<th>Maximum Predicted Total Conventional Sagging Curvature (km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approved Layout (LW101-103)</td>
<td>205</td>
<td>3.0</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>(Report No. MSEC731)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extraction Plan Layout</td>
<td>180</td>
<td>3.0</td>
<td>0.15</td>
<td>0.02</td>
</tr>
<tr>
<td>(Report No. MSEC867)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It can be seen from Table 8.3, that the maximum predicted conventional subsidence parameters based on the Extraction Plan Layout are less than those for the Approved Layout.

8.2.4.  Impact Assessments and Recommendations for the Farm Dams

The maximum predicted total subsidence parameters for the farm dam within the Study Area based on the Extraction Plan Layout are less than the parameters for the Approved Layout for Longwalls 101 to 103. The magnitudes of the predicted subsidence parameters for both layouts are small and the differences do not change the impact assessments for the farm dam. The following summary outlines the potential impacts to the farm dam provided in the report MSEC731:

- The maximum predicted change in freeboard at the farm dam A02d03, based on the Extraction Plan Layout is less than 20 mm. This change in level is not expected to have any appreciable impact on the normal functioning of the dam.
• Farm dams are typically constructed of cohesive soils with reasonably high clay contents, and are likely to be capable of withstanding tensile ground strains up to 3 mm/m without impact. The predicted strains based on the Extraction Plan Layout are greater than 3 mm/m based on the statistical assessment of observed data.

• It is expected, therefore, that cracking and leakage of water could occur in the farm dams which are subjected to the greater strains, though, any cracking or leakages can be easily identified and repaired. Any loss of water from the farm dams would flow into the drainage line in which the dam was formed.

It is recommended that the farm dam is visually monitored as Longwalls 101 to 103 are extracted, such that any impacts can be identified and remediated accordingly. In this way the farm dam within the Study Area can be maintained in a safe and serviceable condition throughout the mining period.
9.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE INDUSTRIAL, COMMERCIAL AND BUSINESS ESTABLISHMENTS

The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the industrial, commercial and business establishments located within the Study Area for Longwalls 101 to 103. The predicted parameters for each of the built features have been compared to the predicted parameters based on the Approved Layout.

As listed in Table 2.1, the following Industrial, Commercial and Business Establishments were not identified within the Study Area nor in the immediate surrounds:

- Factories;
- Workshops;
- Business or commercial establishments or improvements;
- Gas or fuel storages and associated plant;
- Waste storages and associated plant;
- Buildings, equipment or operations that are sensitive to surface movements; and

The only industrial/commercial infrastructure within the Study Area is owned and controlled by MCO.

9.1. Mine Infrastructure Including Tailings Dams or Emplacement Areas

The open cut mine operations include a haul road (OC4 South-west Haul Road) that crosses over Longwalls 101 to 103, a conveyor and associated powerline, the OC1 highwall and an out-of-pit emplacement, the location of which is shown in Drawing No. MSEC867-09. The predictions and impact assessments for the mine infrastructure are provided in the following sections.

9.1.1. Stage 2 ROM facilities and Conveyor

The Stage 2 ROM facilities and conveyor have been constructed. The locations of facilities and conveyor are shown in Drawing No. MSEC867-09. The conveyor crosses diagonally over Longwall 101 to 103 and includes an access road adjacent to the conveyor. The Stage 2 ROM facilities are located adjacent to the maingate of future Longwall 105 and are about 660 m from Longwall 103, or about 4.7 times the depth of cover at that location.

Previously observed absolute far-field horizontal movements from Fig. 4.6 show the upper limit at Ulan Coal Mine for the sites located 4.7 times the depths of cover from longwalls, was less than 60 mm, (however this data includes the H-Line case and the F-Line case where high valley closure movements were observed).

Ignoring sites with high valley closure movements and the multi seam cases, Fig. 4.6 shows the upper limit of previously observed absolute far-field horizontal movements for sites located 4.7 times the depths of cover from longwalls, is less than 40 mm with most data less than the limits of survey accuracy. These low level horizontal movements are not expected to be associated with measurable tilts, curvatures or strains. It is understood that design of the Stage 2 ROM facilities accounted for predicted subsidence movements up to the extraction of Longwall 105.

The predicted profiles of vertical subsidence, tilt and curvature along the alignment of the conveyor, resulting from the extraction of Longwalls 101 to 103, are shown in Fig. C.05 in Appendix C. The predicted incremental profiles for the conveyor, due to the extraction of each of the longwalls, are shown as dashed black lines. The predicted total profiles after the extraction of each of the longwalls, are shown as solid blue lines. The predicted total profiles based on the Approved Layout are shown as red lines for comparison.

A summary of the maximum predicted values of total subsidence, tilt and curvature for the conveyor, resulting from the extraction of Longwalls 101 to 103, is provided in Table 9.1. The values are the maxima anywhere along the section of the conveyor within the Study Area.

Table 9.1 Predicted Total Subsidence, Tilt and Curvature for the Conveyor from the Extraction of Longwalls 101 to 103

<table>
<thead>
<tr>
<th>Maximum Predicted Total Conventional Subsidence (mm)</th>
<th>Maximum Predicted Total Conventional Tilt (mm/m)</th>
<th>Maximum Predicted Total Conventional Hogging Curvature (km⁻¹)</th>
<th>Maximum Predicted Total Conventional Sagging Curvature (km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2300</td>
<td>35</td>
<td>1.3</td>
<td>1.0</td>
</tr>
</tbody>
</table>

The maximum predicted conventional tilt for the conveyor is 35 mm/m (i.e. 3.5%, or 1 in 29). The maximum predicted conventional curvatures are 1.3 km⁻¹ hogging and 1.0 km⁻¹ sagging, which equate to minimum radii of curvature of 0.77 km and 1.0 km respectively.
The predicted strains for the conveyor are provided in Table 9.2. The values have been provided for conventional movements (based on 10 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4).

### Table 9.2 Predicted Strains for the Section of the Conveyor Located directly above Longwalls 101 to 103 based on Conventional and Non-Conventional Anomalous Movements

<table>
<thead>
<tr>
<th>Type</th>
<th>Conventional based on 10 times Curvature (mm/m)</th>
<th>Non-conventional based on the 95% Confidence Level (mm/m)</th>
<th>Non-conventional based on the 99% Confidence Level (mm/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tension</td>
<td>13</td>
<td>10</td>
<td>22</td>
</tr>
<tr>
<td>Compression</td>
<td>10</td>
<td>13</td>
<td>31</td>
</tr>
</tbody>
</table>

The comparison of the maximum predicted subsidence parameters for the conveyor with those based on the Approved Layout is provided in Table 9.3. The values are the maxima anywhere along the section of the conveyor located within the Study Area.

### Table 9.3 Comparison of Maximum Predicted Conventional Subsidence Parameters for the Conveyor based on the Extraction Plan Layout and the Approved Layout

<table>
<thead>
<tr>
<th>Layout</th>
<th>Maximum Predicted Total Conventional Subsidence (mm)</th>
<th>Maximum Predicted Total Conventional Tilt (mm/m)</th>
<th>Maximum Predicted Total Conventional Hogging Curvature (km⁻¹)</th>
<th>Maximum Predicted Total Conventional Sagging Curvature (km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approved Layout (LW101-103)</td>
<td>2300</td>
<td>35</td>
<td>1.3</td>
<td>1.0</td>
</tr>
<tr>
<td>(Report No. MSEC731)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extraction Plan Layout</td>
<td>2300</td>
<td>35</td>
<td>1.3</td>
<td>1.0</td>
</tr>
<tr>
<td>(Report No. MSEC867)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It can be seen from Table 9.3 that the maximum predicted conventional subsidence, tilt and hogging curvature for the conveyor, based on the Extraction Plan Layout, are the same as the maxima based on the Approved Layout. The potential impacts for the conveyor, based on the Extraction Plan Layout, therefore, are the same as those assessed based on the Approved Layout. The predicted subsidence parameters will result in significant movement in the conveyor. It is understood that provision has been made for mine subsidence movements in the design of the conveyor. The potential impacts to the access road include cracking, stepping, rippling and ponding of the road surface.

With mine subsidence movements accounted for in the conveyor design, it is expected that the conveyor could be maintained in a safe and serviceable condition during the mining period.

It is expected that the impacts to the access road could be remediated by standard road maintenance techniques. The repairs would be progressive and, therefore, could be staged to suit the mining of each longwall in sequence.

It is recommended that the conveyor and access road should be monitored as the extraction faces of the Longwalls 101 to 103 are mined near and beneath them, such that any impacts can be identified early and remediated accordingly.

It is recommended that management strategies be developed to maintain the conveyor and access road throughout the mining period.

#### 9.1.2. OC4 South-West Haul Road

A haul road (OC4 South-West Haul Road) is located above Longwalls 102A and 103 as shown in Drawing No. MSEC867-09.

The predicted profiles of vertical subsidence, tilt and curvature along the alignment of the haul road, resulting from the extraction of Longwalls 101 to 103, are shown in C.06, in Appendix C. The predicted incremental profiles for the haul road, due to the extraction of each of the longwalls, are shown as dashed black lines. The predicted total profiles after the extraction of each of the longwalls, are shown as solid blue lines. The predicted total profiles based on the Approved Layout are shown as red lines for comparison.

A summary of the maximum predicted values of total subsidence, tilt and curvature for the haul road, resulting from the extraction of Longwalls 101 to 103, is provided in Table 9.4. The values are the maxima anywhere along the section of the haul road located within the Study Area.
The maximum predicted conventional tilt for the haul road is 80 mm/m (i.e. 8 %, or 1 in 13). The maximum predicted conventional curvatures are greater than 3 km⁻¹ hogging and sagging, which equate to minimum radii of curvature of greater than 330 m.

The predicted strains for the sections of the haul roads above the longwalls are provided in Table 9.5. The values have been provided for conventional movements (based on 10 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis provided in Section 4.4).

The comparison of the maximum predicted subsidence parameters for the haul road with those based on the Approved Layout is provided in Table 9.6. The values are the maxima anywhere along the section of the haul road located within the Study Area.

It can be seen from Table 9.6 that the maximum predicted conventional subsidence, tilt and hogging curvature for the haul road, based on the Extraction Plan Layout, are the same as the maxima based on the Approved Layout. The potential impacts for the haul road, based on the Extraction Plan Layout, therefore, are the same as those assessed based on the Approved Layout. The potential impacts to the haul roads provided in the report MSE731 include cracking, stepping, rippling and ponding of the road surfaces.

It is expected that the impacts to the haul road could be remediated by standard road maintenance techniques. The repairs would be progressive and, therefore, could be staged to suit the mining of each longwall in sequence. It may be necessary to introduce speed restrictions along the road until the appropriate remediation measures have been implemented.

It is recommended that the road and adjacent baffers should be monitored regularly and frequently as the extraction faces of Longwalls 101 to 103 are mined near and beneath them, such that any impacts can be identified early and remediated accordingly.

It is recommended that management strategies be developed to maintain the haul road throughout the mining period.
9.1.3. Out-of-pit Emplacement

The out-of-pit emplacement area is partially located within the Study Area, above the maingate side of Longwall 103. The approved out-of-pit emplacement above Longwall 103 will be completed prior to the extraction of Longwall 103.

The top of the approved out-of-pit emplacement area is proposed to be relatively flat with a top surface level of approximately 530 m to 540 m Australian Height Datum (AHD). The slopes of the batters formed at the sides of the emplacement area are proposed to vary from grades of approximately 1 in 4 to 1 in 6.

The natural surface levels surrounding the edge of the out-of-pit emplacement within the Study Area are close to the proposed finished level of 530 m to 540 m AHD for the out-of-pit emplacement. As a result, there will be minimal to no batters within the Study Area. The maximum depth of fill above Longwall 103 will be about 10 m to 15 m.

The maximum predicted total subsidence due to the extraction of the Extraction Plan Layout at the base of the out-of-pit emplacement is 1900 mm at the north western edge of the out-of-pit emplacement. The maximum predicted total tilts are 55 mm/m and maximum predicted total hogging and sagging curvature are 2.7 km⁻¹ and 2.2 km⁻¹ respectively.

The maximum predicted total subsidence parameters for the out-of-pit emplacement based on the Approved Layout are the same as those for the Extraction Plan Layout for Longwalls 101 to 103. The impact assessments for the out-of-pit emplacement, based on the Extraction Plan Layout, therefore, are the same as those assessed based on the Approved Layout.

It is expected that additional settlement would occur at the top of the out-of-pit emplacement, as the longwalls mine beneath it, due to the consolidation and lateral shifting of the out-of-pit emplacement. Research reports on the response of UK out-of-pit emplacements to mine subsidence movements indicate that this extra settlement can initiate downhill slumping of out-of-pit emplacements.

A detailed discussion on the additional settlement of unconsolidated out-of-pit emplacements is provided in the background report entitled General Discussion of Mine Subsidence Ground Movements (Revision A) which can be obtained from www.minesubsidence.com. An empirical relationship for the additional settlement of unconsolidated out-of-pit emplacements which are directly mined beneath is provided in Fig. 9.1.

The maximum predicted subsidence (S) at the natural surface below the out-of-pit emplacement is approximately 1900 mm and the depth of cover (h) between the natural surface and the mined seam varies from approximately 110 m to 130 m. The ratio of subsidence (S) to depth of cover (h) at the out-of-pit emplacement varies from 0.014 to 0.017, which is beyond the maximum limit of the range of cases considered in Fig. 9.1.

Based on an extrapolation of the linear trend line, from Fig. 9.1 for S/h ratios of 0.014 to 0.017, the potential additional settlement at the surface of the out-of-pit emplacement above the extracted longwalls ranges from approximately 25 mm/m to 30 mm/m, or 2.5% to 3% of the height of the out-of-pit emplacement. This results in a potential additional settlement of the out-of-pit emplacement area above the UG1 longwalls of up to 450 mm. This value may be a conservative estimate as the natural ground slope beneath the out-of-pit emplacement results in fill thickness increasing as the predicted subsidence reduces, i.e. location of maximum predicted subsidence is at the location of minimum fill thickness and vice versa. The maximum predicted total subsidence plus potential excess settlement therefore is approximately 2350 mm.

As discussed above, the predicted subsidence at the natural ground surface and additional settlement of the emplacement area can initiate downhill slumping of the soils in the out-of-pit emplacement area. Other factors such as the presence of natural steep ground slopes, and surface water ingress may increase the risk of downhill slumping of the sides of the emplacement area. Longwall extraction will create depressions in the flat areas of the emplacement and surface cracks, which will increase the risk of water ingress into the emplacement soils during rain periods.
The areas of greatest concern are the possible failure of out-of-pit emplacement slopes above and close to the proposed work areas of the haul roads, the conveyors and the Stage 2 ROM facilities. Consideration could be given to restricting access to areas near the steep slopes, particularly during the active subsidence period, until subsidence movements cease or the risk of slope failure is determined to be very low.

It is recommended, that management strategies are developed for the management of the surface and the slopes of the proposed out-of-pit emplacement area as the Longwalls 101 to 103 are mined beneath the out-of-pit emplacement area. Such management should include surface crack repair and remediation of the ground surface to ensure that adequate surface water drainage is maintained. Settlement and movement of the out-of-pit emplacement should also be monitored as the longwalls are mined beneath it.

9.1.4. The Highwall of the Open Cut Mine

The longwall geometry and distances to the open cut highwalls based on the Extraction Plan layout are the same as those for the Approved Layout. Therefore, the predictions and impact assessments based on the Extraction Plan layout are the same as those for the Approved Layout.

The tailgate of Longwall 102 is located adjacent to the partially backfilled portion of Stage 1 Open Cut. It is recommended that a geotechnical assessment of the highwall is undertaken based on the predicted mine subsidence movements. It is recommended that the high wall is visually monitored and, if the potential for instabilities are observed, then access is restricted adjacent to the highwall.

It is possible that some horizontal movement of the highwalls could occur, towards the open pit, due to relaxation of in situ stresses in the strata as they are undermined. It would, therefore, be prudent to establish survey lines along the top and bottom of the highwalls to monitor the movements as the longwalls are mined. Regular visual inspection of the faces of the highwalls and the tops of the highwalls, as mining occurs, would also be advantageous in order to ensure that any cracking in the strata is identified. In this way, preventive measures can be put in place, before the stability of the highwalls is compromised.
10.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR AREAS OF ARCHAEOLOGICAL AND HERITAGE SIGNIFICANCE

The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the archaeological and heritage sites located within the Study Area for Longwalls 101 to 103. The predicted parameters for each of the features have been compared to the predicted parameters based on the Approved Layout.

10.1. Aboriginal Heritage Sites

10.1.1. Descriptions of the Aboriginal Heritage Sites

There are 17 Aboriginal heritage sites identified within the Study Area which comprise rock shelters with potential archaeological deposits (PAD), rock shelters with artefacts and PAD, isolated finds or artefact scatters. The locations of the Aboriginal heritage sites within the Study Area are shown in Drawing No. MSEC867-10.

A survey was conducted by Niche Environment and Heritage in December 2016 as three sites recorded as open site PAD (PAD 1 Moolarben Coal, PAD 2 Moolarben Coal, PAD 3 Moolarben Coal) within the Study Area on the Moolarben Aboriginal Sites Database and AHIMS register were considered unlikely to be open PADs and more likely to be rock shelters. All three sites were confirmed to be associated with rock shelters during the survey (Niche Environment and Heritage, 2017).

The following sites within the Study Area have been salvaged since the Subsidence Assessment for the UG1 Optimisation Modification was completed (MSEC, 2015) and, as such, revised subsidence predictions and impact assessment for these sites have not been completed:

- MUG1-Mod1;
- MUG1-Mod2;
- S2MC002; and
- S2MC277.

Detailed descriptions of the Aboriginal heritage sites and the survey conducted in December 2016 are provided in the report by Niche Environment and Heritage (2017).

10.1.2. Predictions for the Aboriginal Heritage Sites

The maximum predicted subsidence parameters for each of the Aboriginal heritage sites located within the Study Area is provided in Table D.01, in Appendix D. The predictions have been provided based on the Extraction Plan Layout, as well as for the Approved Layout (LW101-103) for comparison.

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the Aboriginal heritage sites, resulting from the extraction of Longwalls 101 to 103 for the Extraction Plan Layout, is provided in Table 10.1. The predicted tilts provided in this table are the maxima after the completion of all the longwalls. The predicted curvatures are the maxima at any time during or after the extraction of the longwalls.

<table>
<thead>
<tr>
<th>Site Type</th>
<th>Maximum Predicted Total Conventional Subsidence (mm)</th>
<th>Maximum Predicted Total Conventional Tilt (mm/m)</th>
<th>Maximum Predicted Total Conventional Hogging Curvature (km⁻¹)</th>
<th>Maximum Predicted Total Conventional Sagging Curvature (km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock shelter with Artefacts or PAD</td>
<td>2300</td>
<td>65</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>Isolated Find</td>
<td>1950</td>
<td>50</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>Artefact Scatter</td>
<td>2300</td>
<td>50</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
</tbody>
</table>

The maximum predicted conventional tilt for the Aboriginal heritage sites is 65 mm/m (i.e. 6.5 %, or 1 in 15). The maximum predicted conventional curvatures for these sites are greater than 3 km⁻¹ hogging and sagging, which represent minimum radii of curvature of less than 330 m.

The predicted strains for the Aboriginal heritage sites is provided in Table 10.2. The values have been provided for conventional movements (based on 10 times the curvature) and for non-conventional anomalous movements (based on the statistical analysis above solid coal provided in Section 4.4).
Table 10.2  Predicted Strains for the Aboriginal Heritage Sites based on Conventional and Non-Conventional Anomalous Movements

<table>
<thead>
<tr>
<th>Type</th>
<th>Conventional based on 10 times Curvature (mm/m)</th>
<th>Non-conventional based on the 95 % Confidence Level (mm/m)</th>
<th>Non-conventional based on the 99 % Confidence Level (mm/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tension</td>
<td>&gt; 30</td>
<td>10</td>
<td>22</td>
</tr>
<tr>
<td>Compression</td>
<td>&gt; 30</td>
<td>13</td>
<td>31</td>
</tr>
</tbody>
</table>

10.1.3. Comparisons of the Predictions for the Aboriginal Heritage Sites

The comparisons of the maximum predicted conventional subsidence parameters for the Aboriginal heritage sites within the Study Area, resulting from the extraction of Longwalls 101 to 103, with those based on the Approved Layout (LW101-103) are provided in Table 10.3. A comparison of the maximum predicted subsidence parameters for each of the Aboriginal heritage sites located within the Study Area is also provided in Table D.01, in Appendix D.

Table 10.3  Comparison of Maximum Predicted Conventional Subsidence Parameters for the Aboriginal Heritage Sites based on the Approved Layout and the Extraction Plan Layout

<table>
<thead>
<tr>
<th>Layout</th>
<th>Maximum Predicted Total Conventional Subsidence (mm)</th>
<th>Maximum Predicted Total Conventional Tilt (mm/m)</th>
<th>Maximum Predicted Total Conventional Hogging Curvature (km⁻¹)</th>
<th>Maximum Predicted Total Conventional Sagging Curvature (km⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approved Layout (101-103) (Report No. MSEC731)</td>
<td>2300</td>
<td>65</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>Extraction Plan Layout (Report No. MSEC867)</td>
<td>2300</td>
<td>65</td>
<td>&gt; 3</td>
<td>&gt; 3</td>
</tr>
</tbody>
</table>

It can be seen from Table D.01 in Appendix D that there is a reduction in the predicted subsidence parameters at four of the Aboriginal Heritage sites based on the Extraction Plan Layout. The predicted total vertical subsidence at Site S2CM010 reduces slightly from 325 mm to 300 mm and tilt increases slightly from 12 mm/m to 14 mm/m. The predicted curvatures do not change at Site S2CM010. The subsidence parameters for the remaining Aboriginal Heritage sites based on the Extraction Plan Layout are the same as those predicted for the Approved Layout.

The maximum predicted subsidence parameters for the Aboriginal heritage sites, based on the Extraction Plan Layout, are similar to or less than the maxima predicted based on the Approved Layout. The increase in predicted total tilt for Site S2CM010 is small and does not change the impact assessment for this Site. The potential impacts for the Aboriginal heritage sites based on the Extraction Plan Layout, therefore, are similar to those assessed based on the Approved Layout.

10.1.4. Impact Assessments and Recommendations for the Aboriginal Heritage Sites

Open sites containing artefact scatters and isolated finds can potentially be affected by cracking of the surface soils as a result of mine subsidence movements. It is unlikely that the scattered artefacts or isolated finds themselves would be impacted by surface cracking.

Whilst it is unlikely that the scattered artefacts or isolated finds themselves would be impacted by mine subsidence, it is possible that, if remediation works to the surface areas around the Aboriginal heritage sites was required after mining, these works could potentially impact on the Aboriginal heritage sites. A discussion on surface cracking resulting from the extraction of Longwalls 101 to 103 is provided in Section 4.9.

Rock shelters and overhangs in the Study Area are predicted to be subject to similar impacts as described for rock ledges in Section 5.5 (i.e. potential for fracturing of sandstone and subsequent rockfalls).

Rock Shelters PAD 1 Moolarben Coal, PAD 2 Moolarben Coal, and PAD 3 Moolarben Coal are isolated overhangs with the following dimensions (Length x Width x Height):

- PAD 1 Moolarben Coal: 5.0 x 2.5 x 3.0;
- PAD 2 Moolarben Coal: 12.0 x 3.5 x 2.0; and
- PAD 3 Moolarben Coal: 28.0 x 5.0 x 6.0.
It can be seen from table D.01 in Appendix D that the predicted hogging and sagging curvature for all three sites are greater than 3.0 km⁻¹. These sites are at isolated rock outcrops which are generally considered to be at lower risk of impact than continuous lengths of rock outcrop. The orientation of the Rock Shelter can also influence the risk of impact, with rock faces oriented along the direction of curvature being at higher risk of impact. Of the three above sites, PAD 3 Moolarben Coal is considered to have the highest risk that an impact is likely to occur resulting from the extraction of Longwalls 101 to 103. Site PAD 1 Moolarben Coal is a small isolated feature and impact to this site is considered to be unlikely to occur.

Artefact scatters, isolated finds and/or PADs associated with these rock shelters could potentially be affected by rock falls. If impacts are considered likely based on monitoring, salvage activities should be considered based on site significance.

Further details and discussions on the potential impacts on the archaeological sites resulting from the extraction of Longwalls 101 to 103 are provided in the report by Niche Environment and Heritage (2017). Management of Aboriginal heritage sites will be outlined in the Heritage Management Plan.

10.2. Items of Architectural Significance

There are no items of architectural significance within the Study Area.

10.3. Survey Control Marks

There are no survey control marks identified within the Study Area. The locations of survey marks outside the Study Area are shown in Drawing No. MSEC867-10. The survey marks are predominantly located along the Ulan-Wollar Road and Sandy Hollow – Gulgong Railway. The Murragamba Trig Station overlies Longwall 105, 370 m to the south east of Longwall 103 (i.e. outside the Study Area).

At these locations the survey marks will not be subjected to measurable conventional mine subsidence ground movements due to Longwall 101 to 103; however, they may experience far-field horizontal movements as discussed in Section 4.6. The potential impacts on the survey marks based on the Extraction Plan Layout, are the same as those based on the Approved Layout.

It will be necessary on the completion of the longwalls, i.e. when the ground has stabilised, to re-establish the exact location of the survey marks. Consultation between MCO and Land and Property Information (LPI) NSW will be required throughout the mining period to ensure that the survey marks are not used for detailed surveying purposes by others and that they are reinstated at an appropriate time, as required.

It is recommended that management strategies are developed, in consultation with LPI NSW, as required by the Surveyor General's Directions No.11 Preservation of Survey Infrastructure.
11.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE RESIDENTIAL BUILDING STRUCTURES

As listed in Table 2.1, the following residential features were not identified within the Study Area nor in the immediate surrounds:

- Houses;
- Flats or Units;
- Caravan Parks;
- Retirement or aged care villages;
- Associated structures such as workshops, garages, water or gas tanks, tennis courts, and swimming pools.
APPENDIX A.  GLOSSARY OF TERMS AND DEFINITIONS
Glossary of Terms and Definitions

Some of the more common mining terms used in the report are defined below:-

**Angle of draw**
The angle of inclination from the vertical of the line connecting the goaf edge of the workings and the limit of subsidence (which is usually taken as 20 mm of subsidence).

**Chain pillar**
A block of coal left unmined between the longwall extraction panels.

**Cover depth (H)**
The depth from the surface to the top of the seam. Cover depth is normally provided as an average over the area of the panel.

**Closure**
The reduction in the horizontal distance between the valley sides. The magnitude of closure, which is typically expressed in the units of millimetres (mm), is the greatest reduction in distance between any two points on the opposing valley sides. It should be noted that the observed closure movement across a valley is the total movement resulting from various mechanisms, including conventional mining induced movements, valley closure movements, far-field effects, downhill movements and other possible strata mechanisms.

**Critical area**
The area of extraction at which the maximum possible subsidence of one point on the surface occurs.

**Curvature**
The change in tilt between two adjacent sections of the tilt profile divided by the average horizontal length of those sections, i.e. curvature is the second derivative of subsidence. Curvature is usually expressed as the inverse of the **Radius of Curvature** with the units of 1/km (km^-1), but the value of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in km (km). Curvature can be either hogging (i.e. convex) or sagging (i.e. concave).

**Extracted seam**
The thickness of coal that is extracted. The extracted seam thickness is thickness normally given as an average over the area of the panel.

**Effective extracted seam thickness (T)**
The extracted seam thickness modified to account for the percentage of coal left as pillars within the panel.

**Face length**
The width of the coalface measured across the longwall panel.

**Far-field movements**
The measured horizontal movements at pegs that are located beyond the longwall panel edges and over solid unmined coal areas. Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain.

**Goaf**
The void created by the extraction of the coal into which the immediate roof layers collapse.

**Goaf end factor**
A factor applied to reduce the predicted incremental subsidence at points lying close to the commencing or finishing ribs of a panel.

**Horizontal displacement**
The horizontal movement of a point on the surface of the ground as it settles above an extracted panel.

**Inflection point**
The point on the subsidence profile where the profile changes from a convex curvature to a concave curvature. At this point the strain changes sign and subsidence is approximately one half of S max.

**Incremental subsidence**
The difference between the subsidence at a point before and after a panel is mined. It is therefore the additional subsidence at a point resulting from the excavation of a panel.

**Panel**
The plan area of coal extraction.

**Panel length (L)**
The longitudinal distance along a panel measured in the direction of (mining from the commencing rib to the finishing rib.

**Panel width (Wv)**
The transverse distance across a panel, usually equal to the face length plus the widths of the roadways on each side.

**Panel centre line**
An imaginary line drawn down the middle of the panel.

**Pillar**
A block of coal left unmined.

**Pillar width (Wpi)**
The shortest dimension of a pillar measured from the vertical edges of the coal pillar, i.e. from rib to rib.
Shear deformations

The horizontal displacements that are measured across monitoring lines and these can be described by various parameters including: horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index.

Strain

The change in the horizontal distance between two points divided by the original horizontal distance between the points, i.e. strain is the relative differential displacement of the ground along or across a subsidence monitoring line. Strain is dimensionless and can be expressed as a decimal, a percentage or in parts per notation.

**Tensile Strains** are measured where the distance between two points or survey pegs increases and **Compressive Strains** where the distance between two points decreases. Whilst mining induced strains are measured along monitoring lines, ground shearing can occur both vertically, and horizontally across the directions of the monitoring lines.

Sub-critical area

An area of panel smaller than the critical area.

Subsidence

The vertical movement of a point on the surface of the ground as it settles above an extracted panel, but, ‘subsidence of the ground’ in some references can include both a vertical and horizontal movement component. The vertical component of subsidence is measured by determining the change in surface level of a peg that is fixed in the ground before mining commenced and this vertical subsidence is usually expressed in units of millimetres (mm). Sometimes the horizontal component of a peg’s movement is not measured, but in these cases, the horizontal distances between a particular peg and the adjacent pegs are measured.

Super-critical area

An area of panel greater than the critical area.

Tilt

The change in the slope of the ground as a result of differential subsidence, and is calculated as the change in subsidence between two points divided by the horizontal distance between those points. Tilt is, therefore, the first derivative of the subsidence profile. Tilt is usually expressed in units of millimetres per metre (mm/m). A tilt of 1 mm/m is equivalent to a change in grade of 0.1 %, or 1 in 1000.

Uplift

An increase in the level of a point relative to its original position.

Upsidence

Upsidence results from the dilation or buckling of near surface strata at or near the base of the valley. The magnitude of upsidence, which is typically expressed in the units of millimetres (mm), is the difference between the observed subsidence profile within the valley and the conventional subsidence profile which would have otherwise been expected in flat terrain.
APPENDIX B. REFERENCES
References

Minerva Geological Services Pty Ltd, February 2007. EL6288-Stages 1 and 2 Report on Geological Investigations
APPENDIX C. FIGURES
Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 1 Resulting from the Extraction of Longwalls 101 to 103

- **Initial and Subsided Surface Level (m AHD)**
  - LW101: 3.1
  - LW102: 3.2
  - LW103: 3.3
  - LW101 to LW103:
    - Distance along Prediction Line 1 (m):
      - 200 - 1400

- **Extracted Seam Thickness (m):**
  - 3.1
  - 3.2
  - 3.3
  - 3.4
  - 3.5

- **Subsidence (mm):**
  - LW101 to LW103:
    - Incremental Profiles (Extraction Plan Layout)
    - Total Profiles (Extraction Plan Layout)
    - Total Profiles (Approved Layout)
  - LW102:
    - 325
    - 350
    - 375
    - 400
  - LW103:
    - 425
    - 450
    - 475
    - 500

- **Tilt (mm/m):**
  - LW101 to LW103:
    - Incremental Profiles (Extraction Plan Layout)
    - Total Profiles (Extraction Plan Layout)
    - Total Profiles (Approved Layout)
  - LW102:
    - -2
    - -1
    - 0
    - 1
  - LW103:
    - 2
    - 3
    - 4
    - 5

- **Curvature (1/km):**
  - LW101 to LW103:
    - Incremental Profiles (Extraction Plan Layout)
    - Total Profiles (Extraction Plan Layout)
    - Total Profiles (Approved Layout)
  - LW102:
    - -2
    - -1
    - 0
    - 1
  - LW103:
    - -2
    - -1
    - 0
    - 1

Fig. C.01
Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 2 Resulting from the Extraction of Longwalls 101 to 103
Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 3 Resulting from the Extraction of Longwalls 101 to 103
Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Drainage Line 7 Resulting from the Extraction of Longwalls 101 to 103

Fig. C.04
Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Conveyor Resulting from the Extraction of Longwalls 101 to 103

Initial and Subsided Surface Level (m AHD)

- LW101
- LW102A
- LW103

Subsidence (mm)

- Extracted Seam Thickness (m)

Curvature (1/km)

- Incremental Profiles (Extraction Plan Layout)
- Total Profiles (Extraction Plan Layout)
- Total Profiles (Approved Layout)

Distance along Conveyor (m)
Predicted Profiles of Conventional Subsidence, Tilt and Curvature along South-West Haul Road Resulting from the Extraction of Longwalls 101 to 103

Initial and Subsided Surface Level (m AHD)

Distance along South-West Haul Road (m)

LW102A LW103

Subsidence (mm)

Tilt (mm/m)

Curvature (1/km)

Out of Pit Emplacement

Open Cut 1

Ulan Seam (DWS + DTP)

Fig. C.06
## Table D.01 - Maximum Predicted Subsidence Parameters for the Aboriginal Heritage Sites

<table>
<thead>
<tr>
<th>Site</th>
<th>Description</th>
<th>Maximum Predicted Subsidence based on the Approved Layout (LW101-103) (mm/m)</th>
<th>Maximum Predicted Subsidence based on the Extraction Plan Layout after LW101 (mm/m)</th>
<th>Maximum Predicted Subsidence based on the Extraction Plan Layout after LW102 (mm/m)</th>
<th>Maximum Predicted Subsidence based on the Extraction Plan Layout after LW103 (mm/m)</th>
<th>Maximum Predicted Hogging Curvature (mm/m)</th>
<th>Maximum Predicted Hogging Curvature (mm/m)</th>
<th>Maximum Predicted Tensile Strain (LW101-103) (L/km)</th>
<th>Maximum Predicted Tensile Strain (LW101-103) (L/km)</th>
<th>Maximum Predicted Conventional Comp. Strain (LW101-103) (mm/m)</th>
<th>Maximum Predicted Conventional Comp. Strain (LW101-103) (mm/m)</th>
<th>Predicted Conventional Comp. Strain (mm/m)</th>
<th>Predicted Conventional Comp. Strain (mm/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAD 1 Moolarben Coal</td>
<td>Rock Shelter with PAD</td>
<td>2950</td>
<td>1900</td>
<td>1900</td>
<td>65.0</td>
<td>65.0</td>
<td>&gt;3</td>
<td>&gt;3</td>
<td>&gt;3</td>
<td>&gt;3</td>
<td>&gt;30</td>
<td>&gt;30</td>
<td>&gt;30</td>
</tr>
<tr>
<td>PAD 2 Moolarben Coal</td>
<td>Rock Shelter with PAD</td>
<td>2150</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td>2150</td>
<td>3.0</td>
<td>&gt;3</td>
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<td>&gt;3</td>
<td>&gt;30</td>
<td>&gt;30</td>
<td>&gt;30</td>
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<tr>
<td>PAD 3 Moolarben Coal</td>
<td>Rock Shelter with Artefacts (1 artefact) and PAD</td>
<td>2250</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td>2250</td>
<td>1.0</td>
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<td>&gt;3</td>
<td>&gt;3</td>
<td>&gt;30</td>
<td>&gt;30</td>
<td>&gt;30</td>
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<tr>
<td>S2MC009</td>
<td>Isolated Find</td>
<td>2950</td>
<td>1900</td>
<td>1900</td>
<td>50.0</td>
<td>50.0</td>
<td>&gt;3</td>
<td>&gt;3</td>
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<tr>
<td>S2MC010</td>
<td>Isolated Find</td>
<td>2250</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td>2250</td>
<td>3.0</td>
<td>&gt;3</td>
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<td>S2MC011</td>
<td>Isolated Find</td>
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<td>&lt;20</td>
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<td>5.0</td>
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<td>Isolated Find</td>
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<td>&lt;20</td>
<td>&lt;20</td>
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<tr>
<td>S2MC278</td>
<td>Isolated Find</td>
<td>2250</td>
<td>&lt;20</td>
<td>&lt;20</td>
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<td>&gt;3</td>
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<td>&gt;30</td>
<td>&gt;30</td>
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<tr>
<td>S2MC347</td>
<td>Rock Shelter with Artefact Scatter and PAD</td>
<td>225</td>
<td>100</td>
<td>225</td>
<td>5.0</td>
<td>5.0</td>
<td>&gt;3</td>
<td>&gt;3</td>
<td>&gt;3</td>
<td>&gt;3</td>
<td>&gt;30</td>
<td>&gt;30</td>
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<tr>
<td>S2MC348</td>
<td>Rock Shelter with PAD</td>
<td>600</td>
<td>475</td>
<td>600</td>
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<td>12.0</td>
<td>&gt;3</td>
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<td>2300</td>
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<td>S2MC350</td>
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<td>2300</td>
<td>2300</td>
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<td>2250</td>
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<td>&gt;30</td>
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</tr>
</tbody>
</table>

Note: Predicted conventional strains are based on 10 times curvature.
APPENDIX E.  DRAWINGS